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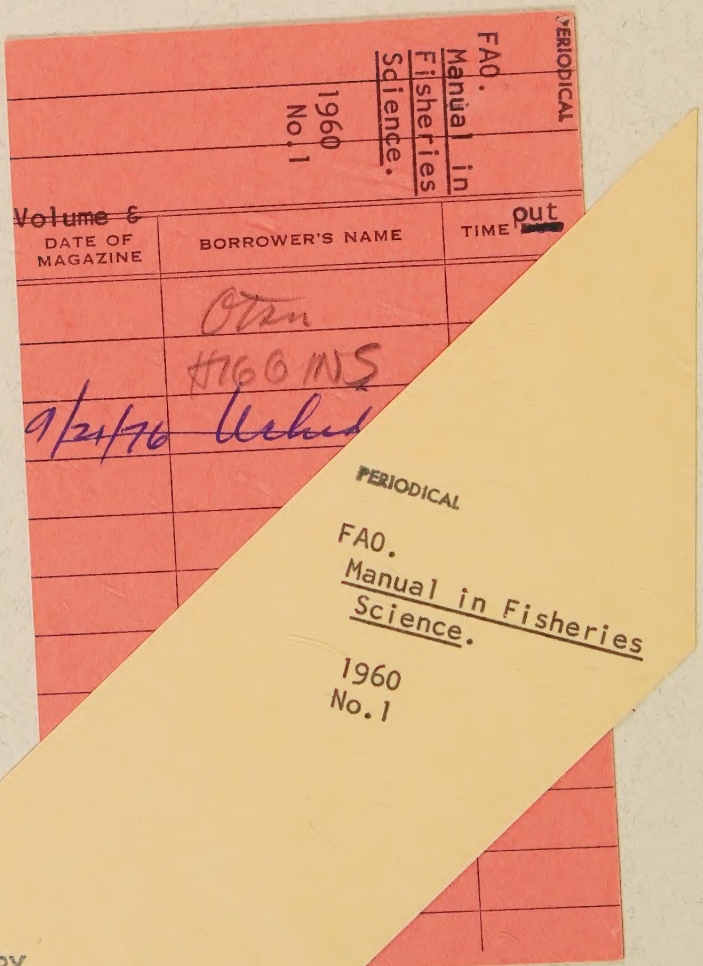

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FAO Manuals in Fisheries Science *No. 1*

General Editor: G. L. Kesteven, D. Sc.

MANUAL OF FIELD METHODS IN FISHERIES BIOLOGY

Provisional Edition

FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS
Rome, 1960

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FOREWORD

by

D.B. Finn, D.Sc.

Several years ago, at one of the earliest meetings of the Indo-Pacific Fisheries Council, attention was drawn to the need for textbooks covering each of the aspects of the new science of fisheries. Proposals were then made, and plans drafted, for a series of manuals for the use of fishery workers in the Indo-Pacific region. Various courses of action to lead to production of these manuals were set in train, but for several reasons progress was very slow. In the meantime, FAO had found through its Expanded Technical Assistance Program and especially through its regional training centres, that a need for such manuals extended far beyond the Indo-Pacific region; in consequence the Fisheries Division undertook to sponsor and assist production of these works on world-wide scope. The present volume then is the first of this series: it is intended that other volumes should follow in close succession.

There can be no doubt about the need for manuals such as those planned for this series. Fisheries science is new, its academic institutions few, and its practitioners far from numerous. It is natural therefore that few efforts should have been made to crystallise in textbook language, ideas and concepts that are even now still taking shape in the minds of their creators. Nor does the Fisheries Division wish to fall into this error and therefore these Manuals will not be textbooks in the usual sense of that term, but rather practical guides describing techniques and plans, and presenting such ideas and views on this science as at present have general currency. The reader must therefore appreciate that production of these manuals is, as the General Editor of the series describes in his Preface, a co-operative enterprise in which authors, consultants and users are joined together in deciding what ideas, concepts, methods and terms have been submitted to and survived sufficient testing to merit inclusion in them. It is because fisheries science is growing rapidly, and as an essential of the publication plan, that the Fisheries Division intends to issue the definitive editions manuals in loose-leaf form to allow for ready modification or expansion of individual sections. I have no hesitation in soliciting the assistance of all fishery workers in the task of revision.

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PREFACE

by the

General Editor

In launching the FAO Manuals in Fisheries Science with this volume on Field Methods, it will be well to give a brief account of the overall plan for the series, besides giving a special account of the present volume.

The Manuals are intended to be vade mecums of practical value to those engaged in fisheries research, and for this reason a volume will be devoted to each of the principal sections of work in which these researches engage. Thus, there will be volumes dealing, for example, with Laboratory Methods, Sampling, Gear Selectivity, and Population Dynamics.

At the same time production of these volumes will provide an opportunity for promoting improvement and standardisation of methods, equipment and terms. For this reason, and considering both the rate at which fisheries science is developing and the obvious scope for its development, the definitive editions of the volumes will be published in loose leaf form. This format will permit revision and expansion of particular sections as these become possible.

In order to serve the basic aim of these volumes, that they should be of most general usefulness, the authors of the initial manuscripts will, whenever possible, incorporate standard descriptions of methods and techniques in their texts. It is part of the programme of the Fisheries Division (as it is of Fisheries Councils and Commissions) to bring such descriptions under review from time to time to determine whether revision need be made of them; the volumes of this series will serve as a repository for such descriptions and as a register of their revision.

In order to ensure that each volume most closely conforms with what general concensus holds to be the present status of theory and methods in its field, arrangements are being made to establish for each volume a panel of consultants to whom the first manuscript is to be sent for scrutiny and criticism. The observations made by the members of a panel will permit authoritative revision of the manuscript. The Fisheries Division trusts that it may rely on the members of each panel to keep the revision of these manuals in view, and to advise it of changes that should be contemplated. At the same time the Division appeals to users of the volumes to advise it of

errors and omissions. In particular the Division wishes to know of features that, added to these volumes, would increase their usefulness. It is the Division's belief that the cooperative effort of authors, consultants and users will result in the production and maintenance up to date of a practical and authoritative encyclopedic work for the use of fishery research workers.

The present volume has been prepared jointly by the following, with principal responsibility for sections, as shown:

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The Division is deeply indebted to these consultants for the careful study they made of the manuscript and their useful suggestions.

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Section 1

PLANNING, RECORDING, AND REPORTING FIELD WORK

1.0 INTRODUCTION

The purpose of this manual is to give guidance to those engaged in fisheries research, in planning, carrying out, and recording their field work. It is intended primarily for beginners and junior workers, but, since it is a compendium of techniques, forms and tables, it may prove useful also to experienced workers.

The primary object of study of these field operations is fish: either single fish to be measured and dissected or to be observed *in vivo*, or groups, schools or stocks of fish to be observed or caught, in order to ascertain their distribution, behaviour and abundance. Theories exercise considerable influence on the choice of operations and techniques, and we may say that theoretical considerations determine, with a view to the practical needs of industry, the objectives of each expedition; however, these objectives compromise with practical issues, such as personnel and equipment, and with weather, to determine the operations to be undertaken and techniques to be employed on each particular occasion.

The bulk of the book consists of descriptions of techniques of observation and measurement which, in various patterns, constitute the operations to be carried out during expeditions. The techniques selected are those in most common use for their purpose, and each is described in detail sufficient to enable a worker to use it consistently and reliably.

An often overlooked aspect of this work is the importance of the care to be taken in keeping records of operations. It is scarcely possible to give too much emphasis to the importance of recording each operation and its results as the work progresses; each observation or measurement must be accurately recorded, correctly identified; and these records must be made in a way to permit of effective and economic treatment of them later. Much information is lost because sets of data or material are ambiguously identified and because the circumstances under which data and material have been obtained are incompletely recorded.

1.0.1. Some terminology

In this book we use the term expedition* generally to refer to all kinds of field travel. This general term includes *cruises*, referring to sea-going work, often with extended periods out of sight of land, *field-trips* referring to essentially land travel with or without a day or two of travel on water, and *visits* referring to occasions when workers go to markets, landing places and processing establishments.

A plan for an expedition comprises a statement of objectives, schedules of staff and equipment and an *operational plan*; the last is a systematic statement of the *observing*, *collecting*, *sampling* and *measuring* to be done during the expedition; each of these operations will be effected, according to the object upon which it bears, by the application of one or more of a number of *techniques* generally using certain *instruments* or *equipment*. Thus, observing of schools of fish may be done by naked eye, above or under water, or through television, or by echo-sounder. The measuring of sea-water turbidity may be done by naked eye against some simple scale, or by means of more precise optical equipment; the measuring of fish may be done with one or other of a variety of measuring boards and instruments and should be done by methods appropriate to each kind of fish. Operations are either *primary* or *complementary*, the former bearing directly on the objects of prime interest to fisheries biology, fish, and the latter on elements of the environment of fish.

1.0.2 Selection and standardisation of techniques

In designing or choosing a technique one must not think only of the manipulative action by which something is measured, or observed, but must think of the technique as involving all the following elements:

a *purpose* for the *measurement* or *observation*, that is, a use for the data to be obtained,

a particular *physical property* to be measured or observed,

equipment with which to make the measurement or observation,

the *manipulation* of the equipment in taking a measurement, or making an observation, including any manipulation of the object being measured,

the *units* in which the measurements are to be recorded,

criteria governing the performance of these manipulations with special regard to precision obtainable with them,

---

* The term is very often used in connection with much more substantial projects than most of those with which this book deals; but we have found no other term suitable.

the *circumstances* under which the technique is applied and the record that may have to be made of them, often including application of secondary techniques,

the *recording* of the results obtained,

the *rationale* governing decisions as to the number of objects to be measured, found chiefly in sampling theory,

the *cost* per measurement, in time or in money.

Throughout this book each technique* is presented, as far as possible, according to the above plan. Let us treat an example in this way and take length measurement of fish for this purpose.

The *purpose* of measuring the length of fish, in fisheries biology, is to ascertain the length composition of the stocks being studied and, by manipulation of the data, growth rate and other characteristics of these stocks. Continuation of such operations, accompanied by environmental studies, permits the research worker to ascertain the influence of the environment on these characteristics and their response to changes in environmental influences.

The *physical property* to be measured may be the total length of the fish, its standard length, or some other dimension, that will reliably represent the size of each fish. The choice of dimension is subject to a number of considerations, no one of which has, necessarily, a priority over the others. Between a number of overall lengths we must judge which permits the most accurate and consistent results with greatest ease and speed; total-length might be easier to measure than length to caudal fork, or than length to caudal base, but for a particular species it might be that measurement of total length (that is, from snout tip to tip of the tail at greatest extension) might be unreliable because of frequent damage to tail tip, or might be slow because of the difficulty of getting consistent extension of the caudal fluke. Or the shape of the fish might make measurement difficult. Here the only solution is to measure a number of fish by each dimension, taking care also to test observer differences, and to analyse the results statistically. It is probably advisable also to time the measurements, in order to obtain a measure of the ease of operation and a basis for calculation of costs. There is a further consideration to be borne in mind, namely, where allometery intervenes. It may be, in some species, that a difference between the rate of growth along a normal axis and that along other dimensions might make measurement along the normal axis less informative than measurement along another. Again, the fish may have been partially butchered so that measurement of total length is not possible; in such

* In the main we are dealing here with quantitative operations by which measurements are made of physical properties. Special techniques of qualitative measurement will be dealt with separately.

cases resort may be made to measurement of some partial dimension, and the relation of the chosen dimension with total length should be ascertained.

By this time the main characteristics of the *equipment* will have been fixed by the choice of the measurement to be made, but further decisions must be made as to the total *units* in which to measure and the *precision* to be obtained. A choice must be made between metric or other system of units, and appropriately to each fish, between various units such as millimetres, centimetres, etc. Consideration must be given here also to problems of parallax error, observer bias, and speed with which the particular measurement can be made to the desired precision. These matters are dealt with in detail in the descriptions of the various types of measuring instruments. In measuring a fish the *manipulation* of it on the board (the most usual instrument) may be of considerable importance. If total length is being measured, the manner of extending the caudal fluke(s) should be standardised appropriately for each species; similar ruless hould be made for other length measurements. The rules for handling movable parts of a measuring board must be followed strictly.

The *circumstances* under which fish are to be measured may play a considerable part in determining what can be attempted. On the deck of a fishing vessel and on market floors, the need to get the fish quickly stowed away or despatched to buyers is generally so great that only the simplest operations can be undertaken. Often, in such cases, the measurer will take only length measurements, from as large a sample as time permits (subject to sampling rules), and will take a sub-sample, of fewer fish, on which to make more detailed measurements. In these cases simpler techniques of measurement may be used, for example, the length may be recorded simply as holes in a celluloid strip. When such simple equipment is used the identity of individual measurements is lost at once and the result simply, and immediately, a length frequency tabulation; this contrasts with the result of more detailed measuring, where each fish is represented by the results of various measurements and observations, say of total length, body proportions, sex, gonad condition, stomach contents, and so forth. Of course, where such other measurements are made, the purposes of the work are broader than those stated at the beginning of this exercise, and in this we have an example of the need to be clear as to what is being done and its purpose; for the present example, are the operations intended to furnish data only on size, or on size classified as to sex or other characteristic, or on other aspects of the population?

The *recording* of length measurements varies according to the technique used. The numbers of fish to be measured in each sample, the number of samples to be take, from each catch of fish or each locality, and the number of catches or localities to be sampled, are matters to be determined, according to the purpose of the operations, and conforming with the rules of sampling theory. These aspects are signified in the above plan under the term *rationale;* they have a very important bearing on the matter of *cost.*

In Sections 2, 3 and 4 of this book techniques are grouped chiefly according to objects, and the characteristics of these objects, to which each technique is to be applied. In general it must be held to be an objective that for each measurement to be made there should be a single technique to be used, but this proposition is to be regarded with caution, and on finding a multiplicity of techniques for a single object, it must not be assumed that there has been no standardisation or that all but one of the techniques could be eliminated after a little work; to do so might be serious error, and since such considerable benefits are to be derived from standardisation, and since also so little success has attended the efforts made to standardise biological techniques, it is worthwhile to consider what standardisation means in this work.

Standardisation is, in fact, part of the more general operation of selecting techniques, in which there are at least three stages. Firstly, decisions must be made as to what is to be measured and the purposes for which the measurement is to be made; too often there have been attempts to institute standardisation before even this decision has been made. Turning again to the example, of fish-measuring, used above, a search of records would reveal that there have been attempts to stipulate a single technique for measurement of fish before the appropriate dimension to be measured had been determined. It is clear that a technique can be specified as standard only for a single and unique physical property; thus, for example, a technique could be specified for the measurement of the total length of *Clupea harengus* of a certain size range, and might, after research, be specified for appropriate size ranges of other Clupeoid species (and thereby be separately specified), but no single technique could be specified for the measurement of total length of all fish.

In the second stage of selection choice must be made of equipment, manipulations and degree of precision, and it is here that the major part of standardisation is effected, Statistical methods can be used in comparing results obtained from the use of different types of equipment and different sets of manipulation; these comparisons may be referred to the desired degree of precision. These statistical tests will evaluate each item of equipment, and each method.

In the third stage, reference will be made to the circumstances under which the technique is to be used and to the frequency (rationale) of use, and perhaps also to cost. The results of statistical test in the second stage may be submitted to further tests with regard to practicability (of use) and economy.

By standardising in this way we should be able to ensure that if a particular instance of a particular physical property were to be measured by a group of workers their results would differ only by unavoidable error; and that all data from several separate research programmes measuring a particular physical property could be treated as though they were the result of the work of a single person or team. However, in much of this work the first stage of selection has not yet been completed, and the differing circumstances under which research in fisheries biology must be carried out demand relaxation of the more strict rules of a standard. Nevertheless, if a standard has been agreed upon for any procedure, departures from the standard should be clearly shown in accounts of the use of the procedure.

1.1 PLANNING OF EXPEDITIONS

Much of the success of an expedition depends upon the planning that has preceded it. An operational plan represents a wish and a forecast: a wish to obtain certain data, and a forecast that certain operations will be performed provided certain conditions prevail. And although bad weather, even if forecast, is likely to hinder and often prevents altogether the conduct of planned operations, still, the more carefully that an expedition is planned and its operations are designed to meet expected conditions, the more likely it is to achieve its objectives.

The first stage in planning an expedition is to decide upon its objectives, which must be done, of course, with reference to practical circumstances which will play such a large part in the operations that can be undertaken. The objectives will be to obtain certain information concerning stocks of fish, or about a particular area: the information required will be specified by the research workers and, as indicated earlier, no attempt will be made here to establish the grounds on which such decisions are made. However, it is within the scope of this book to consider, in general principle, the problem of how a reconciliation is to be made between conflicting objectives and how a selection is to be made from among various nominated objectives.

We have stated earlier than a plan for an expedition comprises a statement of objectives, schedules of staff and equipment, and an operational plan. Whilst the objectives and the operations are virtually inseparable, the former requiring the latter and the latter permitting the former, the relation between staff and equipment on one hand and operations on the other is somewhat different: either staff and equipment are fixed and operations must be selected within their capacity or, if staff and equipment may be modified at will, operations may be planned and staff and equipment provided to accomplish them.

1.1.1 Primary types of operations

1. *Reconnaissance:* - general study of an area to obtain a picture of its main characteristics.

2. *Exploratory fishing:* - Use of various types of fish-searching equipment and fishing gear to ascertain the kinds of fish present in an area and to obtain some idea of the magnitude of the stocks of these. Information would also be obtained on such things as nature of bottom, and sea-conditions, that might affect fishing.

3. *Prospecting:* - Use, in a particular area, of fish-searching equipment and fishing gear, appropriate to one or more species known to be present in the area, to obtain a detailed picture of the distribution of these species and estimates of the magnitude of these stocks.

4. *Experimental fishing:* - Use of fishing gear to determine the properties of the gear itself, or of the entire unit of which the gear is part, especially with regard to its effect on the fish stocks. Comparative fishing experiments are probably the most well known examples of such operations. Experiments to determine the gear most useful in a particular area, or for a particular species or group of species, are included here.

5. *"Census" and routine operations:* - Regular field-work, in markets, at landing places, and on fishing grounds, in sampling fish catches and stocks, to ascertain certain characteristics of the populations under exploitation, such as age, size and sex composition, growth rate, reproduction and recruitment, and mortality.

6. *Analytical operations:* - Bio-analytical work such as tagging, special sampling of non-commercial stocks (eggs, larvae, young fish, fish-food), and research in fundamental biology (e.g. behaviour and physiology), to ascertain characteristics of the stocks and their environment not revealed by any of the preceding operations or by analysis of data on commercial fishing operations.

It will be observed that in the above list each type of operation is defined in terms of objectives and equipment. The foregoing are primary operations for fisheries biology; each is generally accompanied by complementary operations, that is, work in meteorology, oceanography or limnology as a means of specification of the conditions under which the primary operations were carried out operations and essential description of the environment of the fish upon which the primary were applied. The plan of complementary operations is discussed below.

Commercial fishing operations as such are included in the above list only in category 5 where the research operation draws its material by sampling of commercial catches.

1.1.2 Complementary operations

We have defined as primary operations those that are concerned with fish stocks, whilst those concerned with the environment of the stocks have been designated as complementary. It is necessary here to make a stipulation that fisheries biology, in proper definition, is not concerned solely with fish that can be caught and sold; the term "stocks" in the definition of primary operations, refers to all stages of a species, from eggs to the oldest individuals. It will therefore be clear that primary operations must include work relating to eggs, larvae and young fish, as indicated above in category 6. But, more than this, it is also to be stipulated that a broad definition of fishery resources must comprehend at least the food-organisms of the species of economic importance, if not also earlier links in the food chains. Thus, if in the categories of Section 1.1.1 the words "stocks" and "species" are replaced by the word "resources" the scope of the operations to be regarded as primary is

considerably expanded. However, for the present we confine ourselves to operations which have the stocks of economically important species as prime object, and hence we must try to form some rules for a range of other complementary operations to be undertaken if the results obtained from the primary operations are to be fully useful to us.

Exploratory fishing is essentially a study of distribution and therefore, whilst its results are presented primarily in terms of geographic coordinates, its results must be reported as occurrences in relation to observed values of ecological elements known or thought to determine the distribution of the organisms sought. Observations must therefore be made of some physical, chemical and biological elements. Whilst a general pattern of observations of major diagnostic elements, such as temperature and salinity, may be indicated for most expeditions, no generalisation can be made to cover all explorations, and a particular set must be chosen appropriate to the ecological character of each area to be explored.

In *prospecting work* something is already known of the character of the area and the composition of its biota, and the work seeks to give a more precise account of the distribution of the organisms sought and some measure of their abundance. In this situation knowledge of the ecological preferences of the organisms sought is used in deciding which complementary operations should be undertaken. Obviously, these complementary operations should to some extent precede the actual fishing since this should be carried out where it is confirmed by observation that the ecological requirements are met. But since prospecting operations are to advance the knowledge derived from exploratory operations, the plan of complementary operations in prospecting will differ from that of exploration by giving a more precise geographic account of the conjunction of distribution of organisms and ecological elements, or by making more precise measurement of the significant ecological elements, or by measuring additional elements. Work done during prospecting on the abundance of sought species is the initiation of the census and analytical operations, and will seek to establish contours of density of each species being prospected; these will be charted at least geographically, but preferably also ecologically, especially where diurnal, seasonal or other variation in the density patterns is measurable within the prospecting period.

In *experimental fishing* the fullest use is made of ecological indicators to guide the selection of fishing stations, and observations and measurements must be made accordingly. This work will confirm previous evidence or give new evidence from which further studies may be started.

Complementary operations undertaken during "*census*" *and routine* operations are intended to give data from which to ascertain ecological determinants of differences between localities or times in structural features and dynamic properties of a population under study. The particular elements to be observed and measured must be decided upon for each population.

The complementary operations to be undertaken during *analytical* operations are of importance equal with that of the primary operations themselves:

that is, although the primary operations should determine the main features of the expedition plan, the results from the primary operations will be informative only when accompanied by results from the complementary operations. This means that analytical operations are to be treated as a whole, comprising both the primary operations and an appropriate set of complementary operations.

The foregoing brief notes on the kinds of complementary operations to accompany each type of primary operation suggest a few generalisations. Clearly, one of the chief reasons for distinguishing between primary and complementary operations is that the latter are so numerous, and the elements upon which they bear are so ubiquitous, that, unless some logic is found for selecting from among them those that are essential for each type of research there would be a risk of them engaging an excessive proportion of available time and facilities.

It will be clear that here we are dealing with an essentially practical problem, that of ensuring that the complementary operations are neither so scant that the results of the primary operations are of little or no value, nor so numerous and complex that they interfere with the completion of the primary operations.

In the brief notes above the complementary operations serve two purposes. Firstly, to make use of ecological indicators in searching for the situations in which stocks are to be found. Secondly, to ascertain and measure the ecological determinants of structural features and dynamic properties of these stocks. In the first case particular identified elements will be observed and measured. In the second case much more general plans must be formulated and followed.

1.1.3 Choice of operations

At the beginning of this chapter we have referred to the reconciliation of conflicting objectives: by this we meant the drafting of expedition plans to accommodate different types of operations so that a single expedition might accomplish two or more objectives that would seem to call, each for separate expeditions. In the main the conflict we have in mind is that between the fishery biologist, wishing to pursue his study of fish stocks, and the oceanographer (or limnologist) wishing to study the sea (or inland water); in part this problem is to be resolved in terms of the discussion of complementary operations given in Section 1.1.2. Provided those responsible for planning can make a correct identification of what they require to know about the fish

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* It must be kept in mind that in looking at this work in this way we are in no way suggesting that complementary operations are of less value or importance than the primary, in fact: the complementary operations of the programmes with which this book deals are the entire operations of other programmes. However, in these programmes, the specification of the environment is secondary to work directly on fish stocks, even if a specification of some degree is essential to most fishery research.

stocks it should follow that they can make the decisions indicated in Section 1.1.2 concerning environmental characteristics. We would think that this is absolute for a programme in fisheries biology, but for an institute engaged equally, or almost equally, in fisheries research and in "pure" oceanography or limnology it presumably is necessary to decide which type of programme on each occasion will have prior claim on the operational plan of the expedition: if fisheries should have prior claim the plan would be developed as described here with the oceanographic or limnological work carried out either solely as complementary operations, or as complementary operations with additional work as opportunity permitted. If oceanography or limnology had priority then fisheries work would be carried out as opportunity offered.

Similarly for the conflict between technological research and research in fisheries biology.

1.1.4. Operational plan

An operational plan is a statement of 1) operations to be performed and techniques to be used, 2) itinerary to be followed and stations to be occupied, 3) operational routine to be followed at each station.

A *station* is a geographically identifiable point at which operations are carried out, or from which certain operations (e.g. net hauling) are begun on a single occasion. If a particular point is returned to for repetition of operations, or for a new set of them, it is to be regarded as a new station unless a set of stations has been selected in special pattern and each is returned to a number of times—in this case serial identification must be used within the station identification. The position of each station actually occupied should be ascertained carefully and recorded in the log of the expedition. The stations to be occupied during an expedition may be fixed in definite pattern beforehand on the basis of evidence on the distribution of some feature, e.g.: of salinity, current, or some organism that is regarded as an ecological indicator; alternatively, the stations may be decided upon during the expedition as conditions permit and as contemporary observations suggest. Clearly the selection of station sites and of the operations to be performed at each calls for the exercise of careful judgment and resort to all available information. Each occupation of a station should constitute a testing of a hypothesis and, as such, (for certain work) may be as successful with a nil result as with abundant material.

In an expedition plan the operational plan is a set of instructions to the technical (scientific) staff of the expedition, and should be explicit as to what is to be done, where and when, and what modifications of the plan may be made.

The operational plan stands as part of the expedition plan as in the following framework.

EXPEDITION PLAN

Expedition Number (cruise, field-trip or visit)

to (area, locality or position)

Planned duration , commencing , ending

Objectives:

Staff:

Equipment:

- Vessel
- Fish searching gear
- Fishing gear
- Meteorological equipment
- Hydrographical equipment
- Biological equipment

Operational Plan:

- Operations to be conducted
- Itinerary
- Station list (or plan) and operational routines

Records:

1.2 RECORDS AND REPORTS

We divide the records of expeditions into three main groups. Firstly, those of the expedition as a whole, comprising the diary of the technical staff and the cruise and station log (of a ship); secondly, the records of the primary operations; thirdly, the records of the secondary operations.

Some general observations may be made on the designing of forms for use in field-work. It may be observed in principle, that forms are necessary and useful in this kind of work, where so much is routine, in that they systematise the recording operation, and to some extent simplify it. If a form is well designed it reminds the technician of the operations he must perform and of the information he must record, and by its arrangement it should relieve him of much writing since he should be able to enter his observations or measurements as symbols or figures in unambiguously identified spaces or columns.

A well-designed form has certain general characteristics conforming to a number of criteria.

Firstly, it provides space for all information required to be recorded concerning the operation for which it is designed.

Second, it does not call for recording of information that is better recorded in connection with some other operation, and it provides for easy cross-reference between sests of records.

Third, in the case of forms relating to techniques, the design permits the entry of information in the sequence in which the operations of the technique are carried out.

Fourth, it does not require or invite repetition of information common to a number of items nor is space wasted by repetition; for example, if many operations are carried out at a station, the station number should be shown once as common to all these operations and not repeated for each, and if possible there should be a separate sheet (or group of sheets) for each station, with appropriate space for station identification. A common error in form design is to provide a column for information that is entered only once, and for which, therefore, a single line, or "box" would be sufficient.

Fifth, in the case of a form for data that will be treated statistically, as far as possible it should serve the purposes of the statistical operatives as well as of the field worker.

Sixth, it is of size, shape and material suitable for the conditions under which it will be used, and for the convenience of the user.

Seventh, it conforms as far as possible to statisticians' norms concerning size of spaces, width of column, and lay-out

Finally, it is of utmost importance that each set of records (and in fact, that each sheet) should be self-contained and completely clear, and must be usable without reliance on memory. Each form should be designed to achieve this.

It must be noted that the forms in this volume are given only as illustrations of the kinds of forms required, to show the array of data that may have to be accomodated and the manner in which the space of the form may be used for this purpose. Each research programme, however, must test the suitability of each form for the kind of work being done.

1.2.1. Expedition records

The basic scientific record of an expedition is the diary - an hour by hour and day by day record of the activities and observations of the scientific staff of the expedition. Note is kept in the diary of general movements of the expedition, stations occupied (with their position), operations performed showing the objects (kind and number) upon which various techniques have been applied, and any general observations made by the scientific staff (e.g:. of whales or birds seen, particular meteorological and hydrographic phenomena). On cruises the scientific diary is supplemented, and in some respects checked, by the cruise log which records all movements in detail, shows stations occupied and notes the operations performed at each, and records information on the management of the expedition.

In this section of this Manual we deal with only the Cruise and Station Log, leaving to appropriate other sections a discussion of the specialised records to be kept for particular sets of operations.

Form 1.

Cruise and Station Log

a. *Vessel*

b. *Cruise No.*

1 Date	2 Hour start	3 Hour finish	4 POSITION		5 No of Station	6 LOGS FILLED						7 Gear Overboard	8 Remarks and special observations (Fish schools, birds, detritus and plankton, discolouration of water, notes about fishing fleet; etc.).
			4.1 Lat.	4.2 Long		6.1 Met.	6.2 Orig. Ocean.	6.3 Plankton log	6.4 Fishing log	6.5	6.6 Photos		

NOTES ON FORM 1: CRUISE AND STATION LOG

This log is a master record of cruise movements and operations for the scientific programme. It should be kept by the navigation officer assisted by the scientific watch. It should be kept in duplicate, by means of carbon copy. Basically it lists and locates the stations and records the kinds of operations carried out at each by showing in columns 6.1 to 6.6 the scientific logs completed.

4.* For "underway" stations, give position at commencement of the scientific operation for which the station is taken.

6. Indicate with x the logs in which notes are entered for each position and or station.

7. Record the items of gear used.

8. Indicate the change of course and observations on birds, fish schools and pleuston sighted (see instructions in Section 2). For longer descriptions use the reverse side of the log. numbering every note so that it is clear to which observation, station and position the remark belongs.

1.2.2. Writing of reports

Reports of trips should be written as soon as possible, while details are still fresh in the memory. A preliminary expedition repont should be assembled for immediate discussion, and might take the following form.

A. Expedition Plan

1. Copy of original plan.

2. Statement of departures from plan and reasons for these.

B. Work Performed.

1. Summary tabulation of

1. area (s) worked,
2. station occupied,
3. operations carried out,
4. material collected.

2. Statement of records kept (log identification numbers etc) and of where these are lodged.

C. Principal results, so far as these appear prior to detailed laboratory working up.

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* In these "Notes" sections the numbers refer to the columns of the table to which the notes relate, letters refer to entries above the columns (which usually remain the same during the cruise).

Such a preliminary report would be only a working document for record and discussion purposes, and only for internal use. It should be followed by a report developed after material has been worked up, tabulated and placed on maps and diagrams. This second report which can be for wider circulation, should be a self-contained account of the expedition, and preparation of it should not be made contingent in any way on completion of the research programme of which the expedition was part. It should show:

Objectives
Area of operations and itinerary
Staff
Equipment and methods
Work done (stations occupied, operations carried out)
Materials collected
Results obtained.

1.2.3. Storage of records

It is necessary to emphasize the importance of careful and systematic storage of all field records and it is further to be advocated that each institution should maintain a field records unit in which all records are registered and stored when not in use. The field records unit should keep a register of movements of each log, diary and set of papers. Such a system has many advantages over systems in which each officer responsible for original observations retains the records of them as his personal property.

1.2.4. Shipboard photography

To give detailed instructions for photography would mean the preparation of a separate text-book. Reference is therefore made only to a few particular points concerning the use of photography at sea. Firstly, it may be said that it is good practice to be liberal in the use of the camera during an expedition since this may provide valuable record. Of course routine operations do not normally need to be documented in this way, but special operations and particular phenomena such as discolouration of the sea, mass mortalities (most of which require colour film) are most effectively reported with photographic evidence. Special studies, such as of schooling habit of pelagic fish, benefit greatly from photographic record.

Photographs of matters of interest should always be taken at first opportunity; do not postpone in hopes of the most favourable circumstances: they may not come. Whenever possible a photographic plan should be prepared beforehand; this is indispensable for cine record of operations. Special precautions must be taken to protect photographic equipment against the effects of salt spray. Exposed metal parts should be given a light coat of thin oil.

Exposures at sea generally require special precautions in light measuring: reference should be made to photographic manuals for rules on this and on such matters as choice of film.

Section 2

RESEARCH ON FISH STOCKS

2.0 INTRODUCTION

For the technicians for whom this volume is intended, this section deals with the core of the matter. The whole object of research in fisheries biology is to obtain information on fish stocks, and consequently the focus must be on the work described in this Section. Work on the environment described in Sections 4 and 5, while essential, must be held in balance with that of this section as described in Section 1.

Much of the work with which this section deals is carried out in operations of the type 5 in the list of Section 1.1.1 and, being of routine nature, does not require a detailed operational plan for each visit. This must be formulated by the research biologist at the commencement of the programme.

An operational plan for routine operations will take into careful consideration a number of statistical principles covering the choice of samples, the number of samples to be taken at each time and or place and the size of each sample as well as giving precise instructions as to the techniques.

For operations of other types an operational plan will be prepared for each expedition in accordance with the general objectives of the expeditions and in conformity with principles such as those described in Section 1 of this manual.

2.1 COLLECTION AND PRESERVATION OF MATERIAL

Material will be collected in accordance with instructions set out in the operational plan and representative samples will be preserved for transport back to the laboratory for special treatment there.

Whilst the following notes give general indications of the methods by which this material may be collected and preserved, it is to be noted that in certain cases, especially in a case of organs and tissues, there must be very precise specifications of the preserving fluid and the preserving method.

2.1.1 Collecting with experimental gear

Special gear is often used to collect samples of fish which are not normally caught with commercial gear, and small-scale commercial gear is used on research vessels in areas and seasons where no or little commercial fishing is done. Various plankton nets are used to catch fish eggs and larvae, and bottom egg nets, specially designed ring trawls, young fish trawls, are used,

each for its particular purpose. (See further in Section 5 about collection of plankton, benthos and nekton).

Night-light fishing is sometimes done to collect positively phototactic fish and fish larvae. The light with a reflector, in a waterlight cover, is submerged just below the surface, and a fine-meshed dip-net is swept back and forth through the water under the light.

Poisons are sometimes used to collect fish in shallow water, especially among reefs. The best poison for this purpose is ground cube root, 10 kg. of which is sufficient to treat an area of about 10x10 metres if the current is slight and the depth does not exceed 2 metres. The poison should be thoroughly mixed with water in a bucket and then distributed on the surface, in mid-water and on the bottom. The work should be done on slack low tide. Certain species will be affected by the poison almost immediately, while others may show no effects for several minutes. A diligent effort should be made to collect all fish killed by the treatment, regardless of size or variety. To find the very small specimens may require a thorough search of the bottom with the use of a face mask. The area searched for poisoned fish should be larger than the poisoned area, especially "down-stream" of the poison.

Explosives are also used on certain occasions to ascertain the presence of fish or to catch and identify species when schools are sighted at the surface or on echosounders. The use of explosives for catching fish is forbidden in most countries and a special permission from authorities is necessary. In obtaining this permission the person (s) concerned must demonstrate ability in the use of explosives and knowledge of its risks. Depending on the circumstances, the collected material (fish) may be examined on the spot or samples may be taken for preservation. If any kind of fishing gear is used, the *Fishing Log* must be filled (see Section 3). Use may be made of the standard form of label described in the appendix for labelling the collections.

2.1.2 Collecting from commercial catch

Commercial catches are the main source of material for population studies by way of a determination of the relation between catch and the population from which it is drawn. However, the subject of collecting from commercial catches in this sense (chiefly a matter of sampling) is dealt with in another manual.

However, commercial catches, at sea and in the market, are a source of material for other parts of the programme of fisheries biology. At sea the discarded part of the catch may be of considerable importance. Firstly, this part of the catch may consist of undersized fish study of which may furnish important information concerning recruitment and the prerecruit phase of the fishable stocks. Secondly, study of the catch of organisms of no economic importance may be necessary for an understanding of the ecology of the species of economic value.

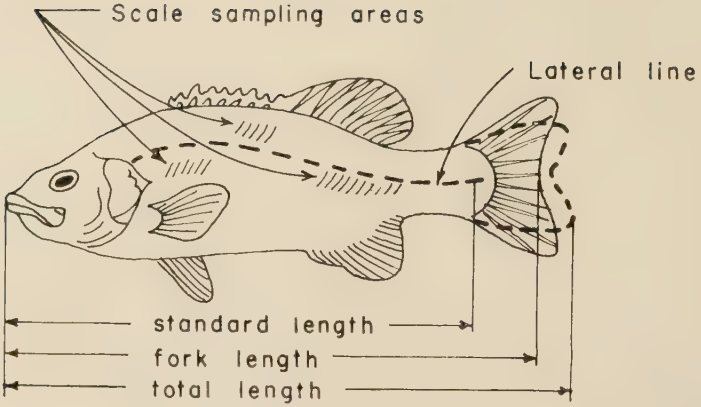

Figure 1. - Common fish measurements and areas of scale sampling (from Lagler)

Figure 2. - (a) Cut for taking otoliths from *Gadus morrhua*
(b) Cut for taking otoliths from *Pleuronectes platessa*

Collecting from commercial catch, at sea or in the market is undertaken according to requirements of the biological enquiries in progress; the material collected will be treated as described in 2.1.3 and 2.1.4. Careful note should always be kept of date and place of collection and of any information obtained concerning the manner in which the organisms were caught, and the place and time of capture.

2.1.3 Collecting separate organs and tissues

Scales are used to determine age and for back computation of growth. The selection of fish from which to take scales depends on many considerations chiefly determined by the sampling requirements of the population studies. Special instructions should be prepared by the biologists to guide the field worker in this matter.

The areas from which scales generally are taken are shown on Figure 1, but the area varies from one group of species to another. Scales should be taken from the side of the fish, avoiding the lateral line since this may have a very high percentage of regenerated scales. Scales are taken from the anterior third of the body of herrings, above the lateral line or under the dorsal fin, and from flatfish from the eye side and most often from the middle of the body. If possible, the fish should be washed slightly to remove scales of other fishes that may have adhered to the body. From 10 to 25 scales are pulled out with forceps or a pocket knife, and placed in small envelopes, each of which is marked with a log number or with data on the fish, such as species, length, weight, sampling place.

Cleaning and mounting of scales, and reading and age-growth calculations from them are described in the Laboratory Manual.

Otoliths are sometimes used for age determination of fish since they also carry regular markings corresponding to events in the life of the fish. They are located in the head of the fish and are part of the auditary apparatus. They are extracted by cutting into the head of the fish and then by being withdrawn with forceps. The manner of cutting into the head depends on the type of the fish and is determined only after some amount of experiment. The normal way of cutting flat fish is with a cut that runs through the eye and the line of immediately posterior to the eye as shown in Figure 2/a Two methods have been used widely for extracting otoliths from cod. The earlier was a cut running through the snout backward along the midline. This cut was made by means of a guillotine on large fish. The more commonly used method now is to remove the surface of the mouth and thereby to expose the otoliths from below. This method can in fact be used also for flatfish, Figure 2/b.

Spines and rays also may carry regular marking and thus be useful for age determination. The selection of rays or spines to be removed for this purpose is a matter for determination by the biologists.

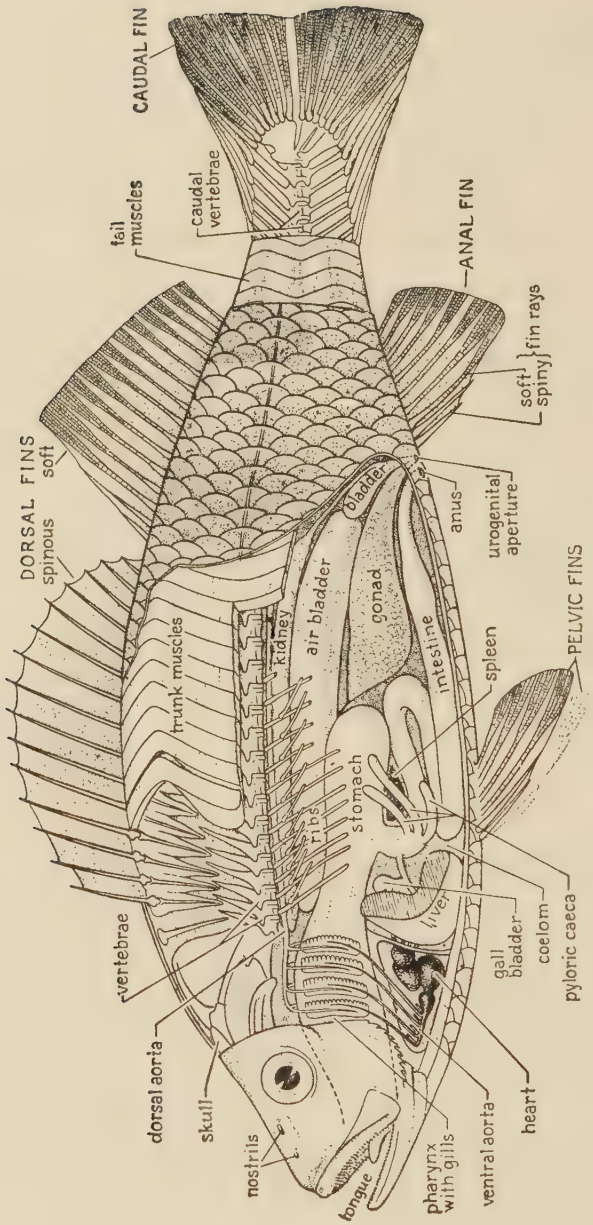

Figure 3. - General structure and morphological features of a fish. (T. I. Storen "General Zoology", McGraw Hill, New York)

Vertebrae may be collected either for racial investigations or for age determination. In the latter case certain particular vertebrae are generally selected and would be indicated by the biologist. The vertebrae required for such studies should be preserved according to instructions provided by the biologist but in general they are held in 60% alcohol. In the former case the entire vertebral column may be required. Counting can sometimes be done at sea but clear instructions must be given by the biologist especially with regard to abnormal vertebrae.

Gonads. The examination of gonads to ascertain the state of maturity is usually done in the field. The gonads should also be weighed in fresh condition, because they change considerably when preserved (see 2.5). The counting of eggs can however be done on preserved material. The gonads are removed by careful opening of the ventral cavity and are preserved in 4% formaline, properly labelled with information concerning the size of fish, its condition etc.

Stomach. Examination of fish stomachs or preservation of their contents should be done as soon as the fish arrive onboard because the enzymes continue to act on food in the stomach after the death of the fish (see 4.6). Stomachs should be collected "at random" whether empty or full, and should be preserved in 8% formaldehyde in order to stop digestion at once.

Gill-rakers may have to be collected for racial studies. They are obtained by taking the entire branchial arch, and are to be preserved in 60% alcohol.

2.1.4. Preservation of biological specimens

Whole fish. A 4% solution of formaldehyde is generally used for preservation. This is made by diluting one part of concentrated formaline (37-40%) with 9 parts of water. This must be neutralized. The volume of material to be preserved should never exceed that of the preserving liquid. Fish less than 10 cm long should be immersed completely in the formaline. Fish 10-30 cm long should have several narrow cuts made in the abdominal wall a little to one side of the midventral line. Fish longer than 30 cm should be injected with undiluted formaline in several places and the belly should be slit in several places.

All preserved specimens should be properly labelled. The colours of the fresh specimens should be recorded.

Scales are usually kept dry in envelopes. They can also be preserved for shorter times (week or two) in water in small tubes.

Otoliths are kept dry in envelopes or on special otolith boards. Alcohol (60%) can also be used for preserving otoliths of some species; such storage facilitates the reading of them.

Vertebrae are usually preserved in 60% alcohol.

Gonads are usually not preserved, but if preservation is necessary, it can be done in 4% formaline. However when egg counting is to be undertaken the eggs are best preserved in Gilson's fluid, of which the formula is:

100 ml 60% alcohol
880 ml water
15 ml 80% nitric acid
9 ml glacial acetic acid
mercuric chloride.

Stomachs are preserved in 8% formaline.

2.2 FIELD IDENTIFICATION

A field officer should familiarize himself with the main species of fish and other organisms in the area in which he is working and form a general idea of the composition of the fauna of his area. Acquaintance with the main species should be such that there should be no errors in identification of them and that any special forms, in the sense of racial differentiation or malformation from disease or other cause, should be readily noted. As to species of less importance and other elements of the fauna, collections and observations will be made as required by the programme. Although this is not the place for an account of taxonomic procedures, or for keys for different groups of organisms, Figure 3 is included for ready reference, and shows the principal external features to which reference is made in descriptions of fish. For detailed taxonomic work reference should be made to standard texts.

2.3 MEASUREMENTS AND COUNTS ON FISH AND SHELLFISH

Measuring linear dimensions of whole or parts of fish is probably the most widely used technique in fisheries biological studies. Such observations are made with special measuring boards, tapes and calipers. Measurements are usually but not always taken along straight lines. Counts of numbers of fin rays etc. are less often made in the field and are only briefly mentioned here.

2.3.1 Length measurements of fish

The length distributions of fish in samples taken on markets or on research or commercial vessels give the simplest index of the composition of the stock from which the catches are being taken. The choice of which of several possible measures of the overall length of the fish is to be used for routine pur-

poses depends on many factors, but primarily on the ease and speed with which the measurement can be taken under the given working conditions, and on the state of the fish (e.g. on whether the caudal fins are usually broken by the time of landing).

It is usually possible to establish a single *basic* (*standardized*) *length* dimension to be used within a particular sampling programme. A basic length may even be adopted for use in several programmes of research on the same species or group of species of fish (e.g. internationally).

The choice of measurements taken to estimate the size composition of whole catches or landings is considered quite separately from that of the attributes for the purpose of distinguishing species, races, or other sub-division of stocks. For the former purpose the desiderable criteria, apart from unambiguous definition and clear recognition, are:

1. ease and speed of measurement with simple equipment under field conditions,
2. existence of a close relation with weight of fish,
3. repeatability by the same or different observers with high consistency of results,
4. existing practice, especially with regard to the accumulation of past data,
5. consistency with measurements which might be made on other fish species at the same time,
6. consistency with measurements of similar fishes being made elsewhere; probably in that order of importance.

Fulfilment of the third criterion clearly depends on the precision aimed at, and both the first and third are related to the design of measuring board. The first three criteria are amenable to experimental test.

Some attention has recently been given to studies of personal error and precision in measurement by comparing observations by different observers. If length is normally distributed there is no bias in the mean, but the variance is increased by observer error; if distributions are rectangular or J shaped (exponential) considerable biases are introduced. However, in comparison with simpling variance these biases are not usually regarded as to serious.

Personal errors can, nevertheless, be significant, but they can be minimized by paying attention to the conditions of measuring. Once a basic dimension has been chosen which is not such as clearly to invite errors and inaccuracies in measurement, the instrument to be used can be designed to facilitate that measurement.

Very often, however, differing conditions of sampling and different states of the fish make it undesirable, or even impossible to measure always the

same dimension; in such cases a *reference length* may be chosen to which all other measurements, including the basic length, can be converted if suitable conversion factors have been determined.

The definitions of length dimension given later in this section apply also to measurements made for comparative morphometric studies. Such detailed and precise measurements are frequently made in the laboratory rather than in the field, but they are considered briefly in section 2.3.4

METHOD OF MEASURING

Overall length measurements are usually made with the fish lying on its right side, snout to the left, on a *measuring board* consisting essentially of a wooden or metal *base* carrying a centre *scale* and having a *head piece* (nose block) against which the snout is gently pressed. The mouth is closed, the fish body and tail straightened along the mid-line and the reading taken from the scale. An attempt is usually made to measure the whole fish in the freshwet condition (that is as near to the relaxed live condition as possible); if *rigor mortis* has set in the fish should be gently flexed just before measuring, In certain circumstances (e.g. during tagging experiments) fish may be measured alive; it may then be necessary to take special steps, such as injection of narcotics, to relax the fish during handling.

Rays and other dorso-ventrally flattened fish may be measured while lying straight on their ventral surfaces; the standardized linear diemnsions of rays is indeed often the disc width rather than overall length.

Large, fat fish present difficulties. Their lengths may be measured with calipers or from point to point along the body surface with a tape.

Commonly measuring is done by observers working in pairs, one of whom places the fish on the board and reads the scale, the other records the measurements called out by the first. Various devices have been used to permit measuring by a lone observer. The surface of a part of the measuring board may be divided in parallel with the central scale and of such a texture that erasable marks may be made with a pencil, etc., or strips of paper may be pinned along the board. In one type of board ruled paper protected by a covering of tinfoil or of cellophane or similar transparent material forms the scale, and is pierced with a needle in the appropriate place at each measurement. The board itself may be dispensed with, and a narrow celluloid strip used on any flat surface (e.g. the deck of the ship). It is pierced at each measurement, and the lengths are read against a scale on returning to the laboratory. Devices recently developed use click-counters, arranged in a row along the measuring board, one for each scale interval. From these the length frequency distribution of a measured sample can be read directly. Use of a simple measuring board, the observations being dictated into a portable tape-recorder, has been tried successfully and there have been proposals for various types of automatic or semi-automatic measuring instruments.

PROCEDURE WHEN THE BASIC MEASURE CANNOT BE USED

The recommended procedure on these occasions is described below.

MEASURING DAMAGED FISH

Suppose that total length is the basic dimension chosen. If an ocasional fish in a sample has its caudal fin damaged, it should not be discarded but its total length should be estimated by comparison with another fish of about the same size, to avoid bias possibly arising because damaged fish tend to be larger or smaller than the average.

If whole samples or large proportions of specimens are damaged, another convenient dimension must be measured, for which there is available a conversion chart based on the calculated regression of total length on that dimension. This may cause a problem in grouping the observations, which is simplified if such measurements are made to millimeter accuracy, converted to total length individually or by millimeter groups and then the calculated total lengths grouped in the normal way. Choice of the other dimension to measure is largely a matter of convenience.

MEASURING DRIED OR OTHERWISE PROCESSED FISH

Dimensionally the most stable part of specimens of many fish species when they are being dried is probably the head. The head length, however, often varies allometrically with total length and conversion then has to be made by using a chart or table based on the regression of total length (or its logarithm) on head length (or its logarithm).

Conversion keys, must be applied only to the stock for which they were determined and should be checked periodically to see whether the regression has changed. If it is found that it does change, it will be necessary to determine the keys anew each season, unless some additional factors are found which permit use of the same key or set of keys. The most likely cause of change in the keys is the probable dependence of the regression used on the growth rate of the fish, it commonly being found that the relative length of the head of a fast growing fish is less than that of a slowly growing fish of the same size. This relation is reflected in the condition factor, and thus usually in the body depth, which tends to be greater in faster growing fish. Body depth and head depth are probably closely related, or at least vary together. This suggests a means of using two measurements such as head depth and head length to estimate total length of dried fish.

OTHER CASES WHERE THE BASIC MEASURE IS NOT USED

In other situations where the recommended standard is not for any reason adopted, conversion tables or charts should be drawn up as described above, from special experimental observations.

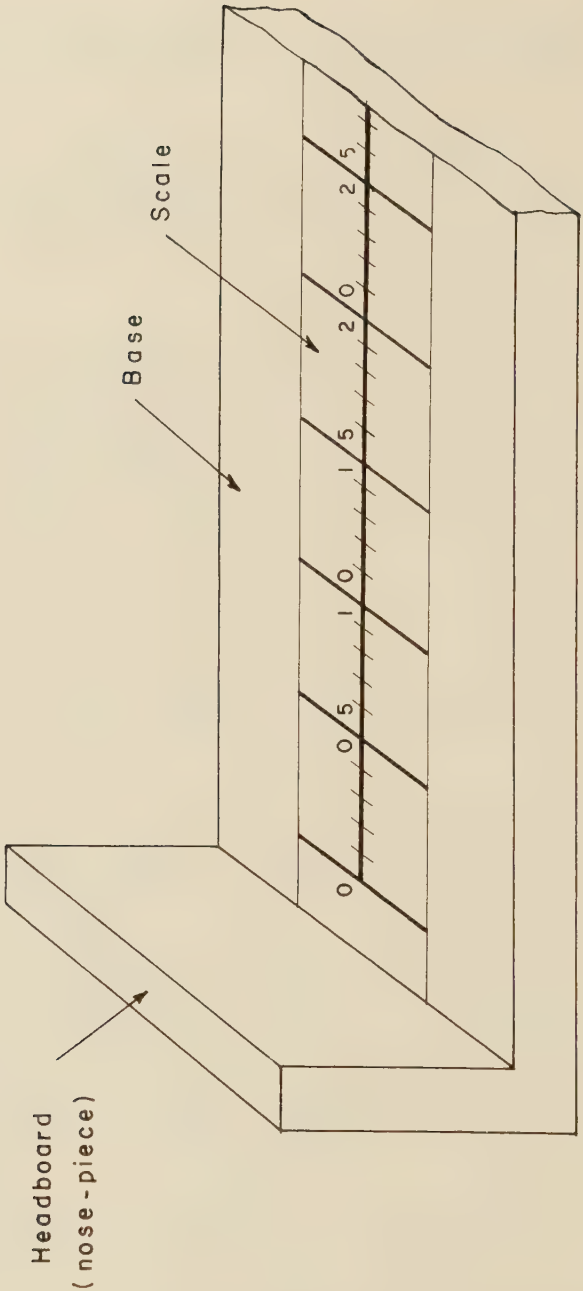

Figure 4. - Measuring board with offset-scale

A particular question to which careful attention should be paid is the degree of freshness and wetness of the measured specimens. It is common knowledge that fish will shrink rapidly on drying. Normally, when measurements are made on fishing craft or on markets at the time of unloading this problem will not arise, but if samples are taken away for later observation, a means of conversion of measurements to fresh, wet condition may have to be employed.

UNITS OF MEASUREMENT, PRECISION AND GROUP SIZE

It has been recommended that the metric system be adopted universally for all scientific measurements relating to the assessments of fish stocks.

The precision with which the results of measurement are stated should be related to, and certainly not higher than, the *accuracy* with which the measurements are or can in practice be made. This accuracy is not usually more than 99%, so that measurements of fish over 10 cm long should not normally be quoted to millimetre precision. The unit interval on the measuring scale is preferably related to the agreed precision of the measurements to be made.

For fish ranging from about 10 to 50 cm in length, quarter-or half-centimetre intervals may be satisfactory.

Choice of the *class interval* is a matter of judgement. For convenience and brevity it is desired to make the class interval as large as possible, subject to the condition that it is also desiderable to be able to treat all values assigned to any one class, without serious error, as if they were equal to the mid-value of the class-interval. These conditions will usually be fulfilled if the interval be so chosen that the total number of classes lies between 15 and 25.

Class limits may be set so that either the limits or the mid-points of the class intervals are convenient round numbers. It is a general principle of measuring that class limits should correspond with a scale-mark on the instrument, and the scale numbers corresponding with the marks should be convenient round numbers. Given these criteria, there are two ways of reading the scale.

1. To the *nearest* scale mark:

2. To the next scale mark *above* or *below*.

The first method is usually not good because judgement of which is the nearest mark takes more time than judgement whether a mark is reached or not, it is more subjective and, in the case of fish measuring, as opposed to the movement of a needle across a dial, it can be biased by the asymmetry of the display of fish and scale. This can readily be demonstrated experimentally.

If measurements are made to the scale unit above or below, with a normal measuring board, the intervals have limits at multiples of whole units and mid-points at half-units. If the scale zero is offset by half a scale unit from the head-piece (see Fig. 4), the resulting classes have whole-unit midpoints and half-unit limits, and the method is equivalent to unbiased reading to the nearest scale unit with a normal board.

Offset boards have some disadvantages. It may be necessary to group classes in different ways for different purposes, and this cannot conveniently be done if the class midpoints, rather than the limits, are whole unit multiples. An offset board also cannot be used easily as a scale for other purposes, unless it has a removable head-piece block one half-unit thick; such an arrangement is undesirable as it unnecessarily complicates the equipment, the removable piece can be mislaid or errors made by the observer not noticing whether it is fitted at the time that measurements are taken.

The differences between measurementes to the nearest unit, or to that above or below, may be conveniently shown by considering the limits and mid-points of, say, the 20 cm group (supposed using ½ cm grouping), the 1 mm groups which make up the ½ cm group, and the 1 cm groups obtained by adding two ½ cm groups.

Method of grouping	Nearest	Next above	Next below
Limits of 20 cm group (by ½ cm)	19.75–20.25	19.50–20.00	20.00–20.50
Mid-point of 20 cm group	20.00	19.75	20.25
Constituent 1 mm groups of 20 cm group	198,199,200 201,202	196,197,198 199,200	200,201,202 203,204
Limits of 20 cm group (by 1 cm)	19.5–20.5	19.00–20.00	20.00–21.00
Corresponding ½ cm groups	None	19.5,20	20,20.5

It should be noted firstly that data given to the nearest unit cannot be combined for groups equal to an even number of the original units, e.g. 1 mm to 5 mm is possible, ½ cm to 1 cm is not.

Secondly, combination of data given to unit below is more obvious to the eye than for data given to unit above, e.g. classing 201 as 20 is quicker than classing 197 as 20. Again, class intervals are customarily designated by their lower limits; thus someone aged 35 years 9 months is referred to as 35 rather than as 36. Several arguments thus weigh against measuring to the *nearest* unit, whether or not this is achieved with the aid of an offset scale.

There is commonly some preference for reading the scale to the unit below rather than to the unit above, but this decision must depend on the design of the measuring board in relation to the dimension chosen for measurement. Thus for fork length reading errors are minimised if the scale numbers run down the centre line of the board. The first number visible beyond the fish is therefore the one read and entered on the recording sheet, and would be the scale mark above. For dorsal extreme length, or body length, - for both of which the scale numbers would most conveniently lie above the centre line - there seems to be no particular advantage in reading to the unit above or below.

We have seen that there are advantages in designating class intervals by their lower rather than by their upper limits. If, as with fork length, there were some small advantage in reading to the scale unit above, but designating the interval by the lower limit, then a scale offset by one whole unit can be used to achieve both ends, but for extreme length it is simpler to read a normal scale to the unit below.

DESIGN OF MEASURING BOARDS

The special requirements have already been outlined above. Here are given some general principles of design, illustrated with reference to the requirements for field measurements of total length of clupeoids, carangids and scombroids not exceeding about 40 cm. For this purpose a half-meter scale would usually be adequate. The board would however, probably often be used to measure other kinds of fish, and then an extension piece, or hinged section could permit measurements up to one meter.

If measures of standard (body) length and other dimension than overall length are to be measured, it may be necessary to fit a sliding cursor carrying a wire which passes over the fish when it is lying on the board. Such boards also sometimes have a mirror on the base; if the measurement is read with the eye in a position such that the wire and its mirror image coincide, parallax error is avoided. Devices of this kind are more often used in the laboratory for morphometric studies than for routine observations in the field.

SOME GENERAL PRINCIPLES OF DIAL AND SCALE DESIGN

The basic data required for rational design of a scale comprise: 1) the total range of the variable to be indicated, 2) the maximum accuracy and sensitivity required in transfer of information, and 3) the maximum equipment and operational error in terms of bias and variation, the latter in this case being determined by repeated observation of the same fish. These known, the scale size, range and number of divisions, can be decided. If there are to few divisions there will be unnecessary loss of information; if too many, time is wasted and a spurious accuracy obtained.

SCALE DIVISIONS

Commonly, for fish of the size range in our example routine measurements are to be made in ½ cm units, special measurements to millimeter units. If the same board is to be used for both kinds of work - and it is convenient if this is possible - then the major scale marks should be ½ cm apart, with intermediate strokes 1 mm apart. The strokes at whole centimeter and half centimeter intervals should be identical, to avoid bias. For the same reason it may be desiderable to have a scale number corresponding with each major mark, though this may not be practical if the numbers are to be engraved the correct size. (Visually, the optimum distance between numbered scale markings is 1 to 2 cm; between unnumbered markings not less than 1 mm).

Scale numbers and marking strokes should contrast well in tone and colour with the scale face. Scale numbers will naturally increase from left to right as the fish is to be measured lying on its right side, and normal visual expectation is that the scale will run in this direction.

There should be some indication, by large numbers or partially thickened lines, of the points which are multiples of 10 cm and perhaps also of the multiples of 5 cm. The scale will then conform with the general principle that all engraved lines and numbers should increase in units, fives or their decimal equivalents.

The ½ cm markings are conveniently continued right across the board which would normally be about 12 cm wide. There should be a median longitudinal line the full length of the board, and the scale numbers should be set about 2 cm above it, the millimeter marks being on the median line or just above it.

If measurements are to be made to the unit above or below with a normal scale the zero of the scale should be level with the head-piece of the board, which would be about 5 cm high.

The following are the recommended dimensions, in mm'ons of engraved numbers and scale marks to be read at normal viewing distance of up to 1 m:

Numbers	Minor	Intermediate	Major
Height	2.3	3.1	4.7
Width or stroke thickness	0.4	0.5	0.6
Scale strokes			
Length	2.3	3.9	5.5
Width	0.4	0.5	0.6

With a dark character on a light background a height to stroke thickness ratio of about 6:1 is best; with a light character on dark, a ratio of 10:1 is better. In general the optimum height to width ratio of the character itself is 3:2.

It is sometimes found useful to have a bevelled edge to the base of the board, to prevent fish sliding off; under certain conditions, however, this is a hindrance rather than an advantage. The board can usefully have a carrying handle, and if it has attached surfaces on which measurements can be written by a lone observer, it should have a hole or eye for the attachment of a pencil by string, or similar arrangement.

DEFINITIONS OF LINEAR MEASUREMENTS

Overall lengths may be measured fron the snout (U, the position of the maxillary symphysis) or from the tip of the lower jaw (L, the mandibular symphysis). Measurements from L are taken with the mouth closed. If the lower jaw projects much beyond the upper jaw measurement from S may necessitate provision of a special "stepped" nose-piece on the measuring board.

There are three main overall length measures in common use. These are roughly illustrated in Fig. 1. *Standard length*, the standard dimension of taxonomy, is properly measured from U to the tip of the hypural bone (urostyle). In practice it may be measured to some external feature more or less corresponding with the latter point; this would vary from one species to another but examples are the last scale or point of silvering, to edge of skin pigment (determined by scraping away the posterior scales), to tip of fleshy peduncle, or to the keel. *Fork length* is measured from U or L to the cartilaginous tip of the shortest, or median, caudal fin ray. It may be difficult to measure if the tail is split. *Total length* is measured from U or L, to the tips of longest caudal fin rays, in several possible ways. Measurement may be taken to the tip of the dorsal lobe, of the ventral lobe, or of the longer of the two, or some average of them both (such as to the mid-point of a line joining the two tips or to the point where such a line crosses the median longitudinal axis). The tail fin may be in the extended position to give *normal* (total) *length* or the tips of one or both caudal lobes may be drawn to the longitudinal axis *extreme* (total) *length*. Sometimes total length measurements are made with the caudal lobes partially drawn together so that their outer edges are parallel to each other and to the axis. It is therefore clear that precise instructions must be given as to the dimension to be measured and the mode of measuring. In particular, if a *normal length* is the chosen dimension, it is necessary to standardise the procedure of laying the fish on the board. A common method is to place the head of the fish against the nose-piece with the right hand, hold the fish in position with the left hand, and use the right hand to straighten the body of the fish and extend its tail with a single stroking movement. A common type of measuring board is illustrated in Fig. 4.

There follow useful sets of notation and definitions for positions and linear measurement, which are applicable to many types of fish; they are illustrated with reference to a scombroid in Fig. 5.

Positions are defined as on the left-side of the fish unless stated to the contrary. When side-to-side comparisons are being made, or if necessary for

other reason, distinguish by prefixing "r" or "g" (right or greater) to the notation (or term). This rule may be especially applicable to the dimensions Ph and Vh.

Lower case letters are used by themselves in the notation where the dimension is not defined with respect to two fixed points, e.g. q, b, g. Otherwise d stand for "diameter", h for "depth", and g for "greatest".

Overall length measurements are always made between perpendiculars along median longitudinal body axis, from L or U with mouth closed. Measurement is understood to be from L unless otherwise specified, thus e.g.

UX Upper (or "maxillary") dorsal extreme length.

Longitudinal measurements other than overall length are also often made between perpendiculars, using a measuring board with, for example, a sliding cursor. When they are made radially from point U, using calipers as is recommended, the symbol for the dimension should be in parentheses, and the name followed by the qualifying term "(direct)". Point-to-point measurements are sometimes made on big fish, e.g. tunas, by tapes. They would be indicated by the word "(surface)"; they are not generally recommended. The term "radial" is not recommended to be applied to point-to-point measurements as it invites confusion with fin-ray counts.

All measurements listed from LX to LM and also their "Upper" equivalents are grouped under the general name Total length, LT. LM has also been called "bilobular length" and "total auxiliary length". It is rather difficult to measure.

The word "extreme" is used in LX, LX' and LX" instead of "maximum" to avoid confusion with the asymptotic size referred to in growth studies. "Greatest" is as a possible alternative to "extreme" but invites confusion with "greater" for which a suitable alternative cannot be found.

LF and LF' have also been called "median length" or "mid-caudal length". The term "standard length" has on occasions been applied to the distance LB as well as to the LS series; this usage is *not* recommended. It is not known that the ventral body length, LB', has ever been used in practice.

"Depth" is used in terms from Oh to q instead of the alternative "height" to avoid possible confusion with fin heights as measured by length of rays. The ambiguous term "width" is not recommended. Again "width" is not recommended as an alternative to "breadth" in terms for PP and b but "thickness" would be suitable.

Pectoral and ventral fins, Ph and Vh, are usually measured in their folded positions opposed to body size (to keep rays straight) from foremost visible point of insertion to the distal tip of the membranous edge.

In measurements of eyes the limits of Id, Ih and Ig are the boundary of the iris with the black tissue. Ig and Eg are not necessarily equivalent to either Id or Ih Ed or Eh respectively.

The method of measuring g, in particular the permissible degree of constriction of the belly, remains to be defined precisely. Other girth measurements might be more consistent and perhaps related to conditions relevant to selectivity problems, e.g. if taken level with Y or D1. An appropriate notation could be gY, gD1, etc.

Spread caudal distance NN' has been used for tunas.

In various types of fishes certain of the dimensions listed may be virtually indistinguishable. Thus in the mackerel *Rastrelliger* LM = LM', LS = LS'', UJ = UO', UY = UJ', and so on.

LINEAR DIMENSIONS: DEFINITIONS AND NOMENCLATURE

Definitions of position

U	Maxillary symphysis
L	Mandibular symphysis
OO	Anterior edge of orbit
O'	Posterior edge of orbit
J	Posterior edge of mandible (buccal commissure)
Y	Gill-cover notch
G	Posterior bony edge of operculum
G'	Posterior membranous edge gill-cover
P	Anterior point insertion first pectoral fin ray
D1	Insertion of anterior dorsal (intersection anterior margin first dorsal spine, fin held erect, with the contour of the back)
D1'	Position last ray of anterior dorsal
D2	Insertion first ray of posterior dorsal
D2'	Position last ray of posterior dorsal
Z	Anterior edge or cloaca
A	Insertion first anal fin ray
A'	Position last ray of anal
B	Insertion dorsal lobe caudal fin
S	Posterior tip urostyle (forward protuberance of hypural blade)
S'	Posterior edge of fleshy peduncle or of pigmented zone
S''	Point of upper caudal keel
S'''	Posterior limit of silvering (either last scale of the lateral line or the posterior limit zone of the scale covered of the peduncle)
F	Cartilaginous tip of shortest (median) caudal ray
F'	Membranous edge of caudal fin at fork
N	Distal tip longest dorsal caudal fin ray, lobe normally extended
N'	Distal tip longest ventral caudal fin ray, lobe normally extended
M	Point where line NN' intersects median longitudinal axis
M'	Mid-point of line NN'
X	Distal tip longest dorsal caudal fin ray, lobe brought to median longitudinal axis
X'	Distal tip longest ventral caudal fin ray, lobe brought to median longitudinal axis

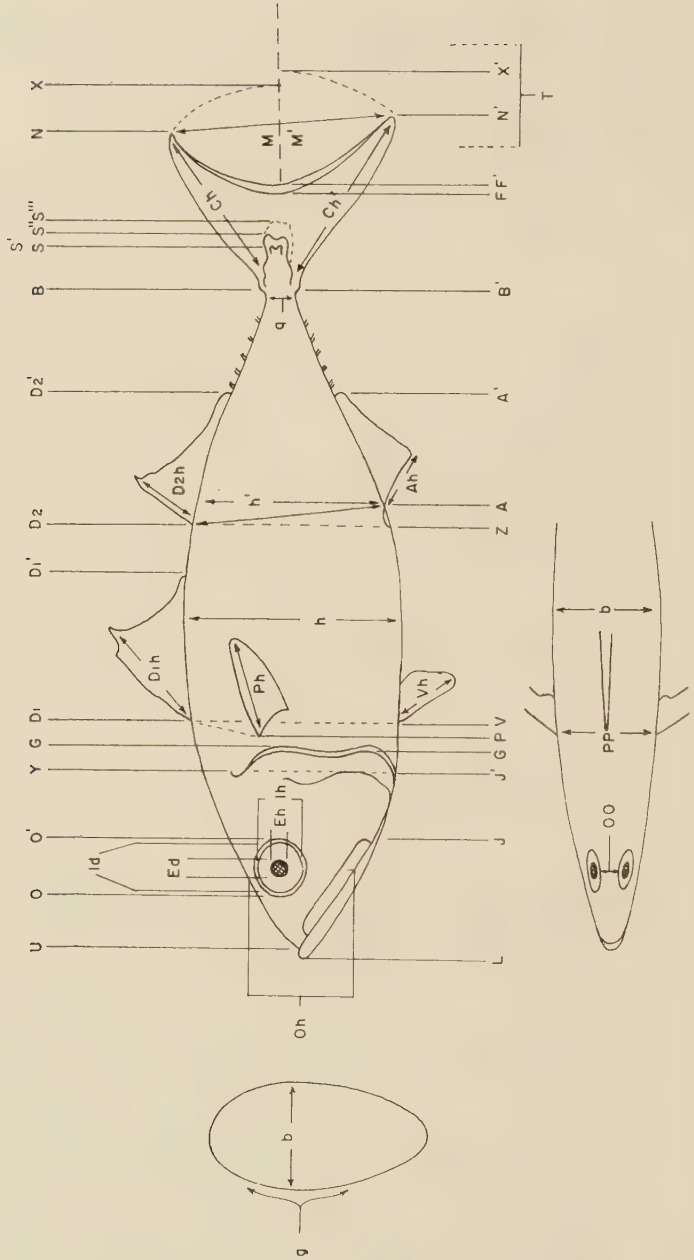

Figure 5. - Body measurements of fish
(see text for definitions and nomenclature, pp. 33-36).

Overall length measurements

LT and UT	Total length (any extreme or normal length)
LX	Dorsal extreme length
LX'	Ventral extreme length
LX"	Greater extreme length (LX or LX', whichever is greater)
LN	Dorsal normal length
LN'	Ventral normal length
LN"	Greater normal length (LN or LN', whichever is greater)
LM	Median normal length
LM'	Mean normal length
LF	Mid-caudal length
LF'	Fork length
LS	Standard length to urostyle (or to some external feature corresponding with it, see commentary)
LS'	Standard length to peduncle (or to pigment under scales)
LS"	Standard length to keel
LS"'	Standard length to silvering
LB	(Dorsal) Body length

Other longitudinal measurements

UJ	Maxillary sheath length
LJ'	Mandibular length
UO	Snout length
UY	Upper head length
LG	Opercular head length
LG'	Gill cover head length
Lg	Greatest head length
OO'	Orbital diameter
Id	Longitudinal iris diameter (cf Ih and Ig)
Ed	Longitudinal pupil diameter (cf Eh and Eg)
O'Y	Post-orbital distance
UD1	Pre-anterior dorsal distance
UP	Pre-pectoral distance
UV	Pre-ventral distance
UD2	Pre-posterior dorsal distance
D1D1'	Anterior dorsal fin base length
D2D2'	Posterior dorsal fin base length
UA	Pre-anal distance
AA'	Anal fin base length

Vertical measurements (perpendicular unless otherwise stated)

Oh	Orbital depth (from orbital crest to lower edge of maxillary, passing over middle of pupil)
Ih	Perpendicular iris diameter
Eh	Perpendicular pupil diameter

YJ'	Head depth
D1P	Back depth (oblique)
D1V	Anterior dorsal depth (or dorso-ventral depth)
h	Greatest depth
D2Z	Posterior dorsal depth
D2A	Dorso-anal depth (slightly oblique)
h'	Perpendicular anal depth
q	(Least) peduncle depth

Lateral measurements

PP	Pectoral breadth
b	Greatest breadth
OO	Interorbital distance (at level of pupil-centres)

Other measurements

D1h	Anterior dorsal height (distance from insertion to tip of longest spine)
D2h	Posterior dorsal height (distance from insertion to tip of longest spine)
Ph	Pectoral fin length
Vh	Ventral fin length
Ah	Anal fin height
Ch	Dorsal caudal fin length
Ch'	Ventral caudal fin length
Ch''	Greater caudal fin length
Ig	Greatest iris diameter
Eg	Greatest pupil diameter
g	Greatest girth
VV	Length of inter-ventral flap
NN'	Spread caudal distance

Skeletal dimensions

Ax	Axial length (anterior face of vertebra 1 to tip of urostyle)
Sk	Skull length (maxillary symphysis to posterior occipital boundary)
An	Anatomical length (= Ax + Sk)

2.3.2. Length measurements of molluscs

1. *Bivalves*

The measurements are shown in Figure 6.

(i) *Length of shell.* The greatest measurement in an antero-posterior direction, this is usually approximately parallel with the axis of the hinge.

(ii) *Width of the shell.* The greatest measurement in a dorso-ventral direction, this is usually approximately at right angles to the axis of the hinge and approximately at right angles to the length measurement.

In shells with very irregular shapes, as the oyster, the length is not always greater than the width.

(iii) *Depth of the shell.* The greatest measurement at right angles to the plane of the above two measurements.
Measurements are made with callipers or measuring boards.
References: Loosanoff, V.L. and Nomejko, C.A. 1949 "Growth of oysters, *O. virginica* during different months", *Biol. Bull.*, Woods Hole, 97 (1): 82–94

2. *Gastropods*

The usual measurement is the length or height of the shell, being the maximum measurement from the tip of the whorl to the tip of the shell.

References: Warren, P.J. 1958 "A device for rapid single-handed measurement of shellfish", *J. Cons. int. Explor. Mer.* 23 (3): 440–2.

2.3.3 Measurement of crustaceans

Lobsters, crawfish, shrimps, prawns. The length of the carapace is the minimum length by callipers from the inside of the eye socket to the posterior margin of the carapace. In some cases (Lobsters) the measurement will be parallel with the mid-line, in others (some shrimps) it will be from the eye socket to the centre of the dorsal margin of the carapace. *Crabs. The width of the carapace* is the maximum measurement across the carapace, including the spines, if present, at right angles to the median line.

References: Cole, H.A. and Mistakidis, M.N. 1953 "A device for the quick and accurate measurement of carapace length in prawns and shrimps", *J. Cons. int. Explor. Mer.* 19 (1): 77–9.

2.3.4 Morphological measurements and observations

In section 2.3.1., above, the principal positions on the body are defined. The measurements and observations described below are usually made for special studies (e.g. racial studies). The measurements vary from family to family of fish and only a few examples are given. In every case the research biologists must give precise instructions concerning the sampling and the accuracy in the measurements. Records are to be kept on a form such as that exemplified in Forms 3 and 4.

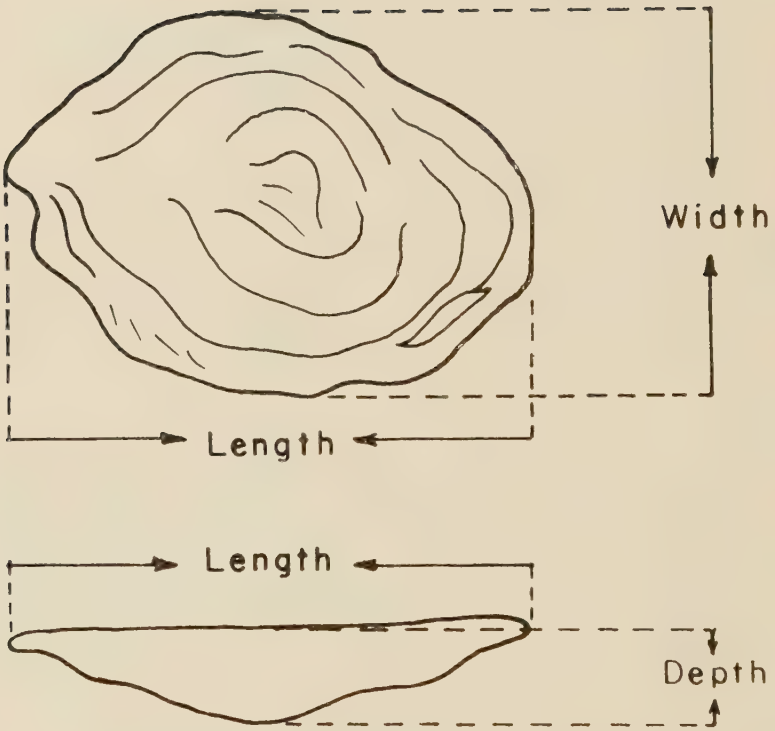

Figure 6. - Measurements of shellfish

a) BIOMETRICAL MEASUREMENTS FOR CLUPEOIDS

Snout to the insertion of the anal fin.

Snout to the insertion of the ventral fin.

Head length - distance from the tip of the snout to the most posterior point of the margin of the subopercle.

Snout to the insertion of the dorsal fin.

For the measurements of sardines the following dimensions have been defined by Ruivo (1957)*:

Length to the fork (LF), (Zoological length) - Distance from the end of the nose to the end of the middle rays of the caudal fork - the fin being flattened out.

Length of the head (LL') - Distance from the end of the nose to the backward bony edge of the operculum (L').

Predorsal distance (LD) - Distance from the end of the nose to the forward origin of the dorsal (intersection point of the forward edge of the first ray of the dorsal - D - with the outline of the back, the fin being flattened out).

Prepectoral distance (LP) - Distance from the end of the nose to the anterosuperior origin of the pectoral (intersection point of the forward edge of the first ray of the pectoral (P) with outline of the flank - the fin being slightly lifted up).

Preventral distance (LV) - Distance from the end of the nose to the anterior origin of the ventral (intersection point of the forward edge of the first ray of the ventral - V - with the contour of the abdomen, the fin being extended).

Preanal distance (LA) - Distance from the end of the nose to the forward origin of the anal (intersection point of the forward edge of the first ray of the anal - A - with the outline of the abdomen - the fin being extended).

Maximum height (H) - Vertical distance, at right angles to the axis of the fish, between the dorsal and abdominal outline, being measured at the forward origin of the dorsal.

Maximum thickness (E) - Thickness of the body measured between the two points of the flank such as are defined by the intersection of the lateral line with a plan perpendicular to the axis of the fish (transversal plan) and passing by the forward origin of the dorsal.

Length of the dorsal (DD') - Distance from the forward origin of the dorsal (D) to the backward edge (intersection point of the backward edge at the last ray (D') with the outline of the back, the fin being extended).

Length of the anal (AA') - Distance from the forward origin of the anal - A - to its backward edge (intersection point of the backward edge of the last ray (A') with the outline of the abdomen, the fin being extended).

* Ruivo's original notation and terminology are retained.,

Length of the pectoral (PP') - Distance from the antero-superior origin of the pectoral - P - to the backward end of the longest ray - the pectoral being extended on the side of the fish in its normal position.

Diameter of the eye (OO') - Vertical diameter of the visible part of the eye, i.e. the distance between the upper edge and the lower edge of the orbit.

b) BIOMETRICAL MEASUREMENTS ON GADOID FISHES

(From LeGall, J., 1952 *J. Cons. int. Explor. Mer*, 18(2):236-240)

Snout to insertion of first dorsal: the distance from the tip of the snout to the base of the 1st ray of the 1st dorsal.

Length of the first dorsal: measured from the 1st ray to the posterior extremity of the 1st dorsal.

Snout to the end of the 1st dorsal.

Snout to insertion of dorsal: the distance from the tip of the snout to the base of the 1st ray of the 2nd dorsal.

Length of the 2nd dorsal: measured from the base of the 1st ray of the second dorsal to the posterior extremity of the 1st dorsal.

Snout to the end of the 2nd dorsal.

Snout to insertion of 3rd dorsal: the distance from the tip of the snout to the base of the 1st ray of the 3rd dorsal.

Length of the 3rd dorsal: as for Length of the 2nd dorsal.

Snout to the end of the 3rd dorsal.

Snout to insertion of ventral: the distance from the tip of the snout to the origin of the ventral.

Snout to insertion of anal: the distance from the tip of the snout to the insertion of the first ray of the anal fin.

Length of the anal: measured from the insertion of the 1st ray to the posterior extremity of the anal fin.

Snout to the end of the anal.

Snout to the insertion of pectoral: the distance from the tip of the snout to the origin of the 1st ray of the pectoral fin.

Length pectoral: measured from the origin of the 1st ray to the posterior extremity of the pectoral fin.

Head length: the distance from the tip of the snout to the posterior extremity of the opercle.

Pre-orbitary distance: the distance from the tip of the snout to the anterior margin of the eye.

Post-orbitary distance: the distance from the tip of the snout to the posterior margin of the eye.

Diameter of the eye.

Greatest depth - measured from the insertion of the 1st ray of the 1st dorsal.

NUMERICAL CHARACTERS (ORIGINAL NOTATION)

N1Dr - number of the 1st dorsal rays.

N2Dr - number of the 2nd dorsal rays.

N3Dr - number of the 3rd dorsal rays.

NAr - number of the anal rays.

NGR - number of gill rakers: observed on the inferior arm of the first branchial arch (anterior of the left side).

NVe - number of the vertebrae: counted after the first cervical vert. immediately after the condylus (not counted) till the last caudal vert. (urostyle not included).

c) BIOMETRICAL MEASUREMENTS ON TUNAS

(From Marr, J. and M. Schaefer, 1949, Definitions of body dimensions used in describing tunas. *Fish Bull., U.S.*, 51(47):241-4.)

Head length: distance from the tip of the snout to the most posterior point of the margin of the subopercle (depressing the fleshy flap extending posteriorly).

Snout to insertion of 1st dorsal: distance from the tip of the snout to the intersection of the anterior margin of the 1st dorsal (erected) with the contour of the back.

Snout to insertion of 2nd dorsal: distance from the tip of the snout to the intersection of the anterior margin of the 2nd dorsal (raised) with the contour of the back, marking the point with a scalpel.

Snout to insertion of anal: distance from the tip of the snout to the insertion of the anal (determined as the 2nd dorsal).

Snout to the insertion of ventral: the distance from the tip of the snout to the intersection of the anterior margin of the ventral, when the fin is extended, with the contour of the body.

Greatest depth: the greatest vertical distance between dorsal and ventral contours.

Length pectoral: the distance from the insertion of the pectoral to the most posterior point, taken with the fin extended posteriorly and opposed to the side.

Pectoral insertion to insertion of first dorsal: the distance from the insertion of the pectoral fin to the insertion of the 1st dorsal.

Length base first dorsal: the distance from the insertion of the 1st dorsal to the insertion of the 2nd dorsal.

Length base second dorsal: the distance from the insertion of the 2nd dorsal to the intersection of the posterior margin of the 2nd dorsal with the contour of the back.

Spread caudal: the distance between the dorso-posterior extremity of the caudal and the ventro-posterior extremity of the caudal. (When caudal fin is not frayed or shrunken.)

Length longest dorsal spine.

Length first dorsal spine.

Length second dorsal: the distance from the insertion of the 2nd dorsal end with a fin in a normal position. Note that the fin is often extended in a long filament and care should be taken to notice if this extension is frayed.

Length anal: the distance from the insertion of the anal fin to its distal end. Remarks as before.

Length longest dorsal finlet: the distance from the insertion of the longest dorsal finlet to the end of its posterior filament.

Diameter of iris: the greatest diameter measured to the margin of the yellow iris and the adjoining black tissue.

Length maxillary: the distance from the tip of the snout to the posterior end of the maxillary.

Least depth caudal peduncle: the least verticle distance between the dorsal and ventral contours of the caudal peduncle.

Greatest width caudal peduncle at keels: the greatest horizontal distance between the lateral contours including the keels (not broken or shrunken).

Number of first dorsal spines: the total number of spines discernible with the first dorsal held erect and with no dissection.

Number of dorsal finlet: the number of finlets following the second dorsal and beginning from the caudal and counting separately the finlets attached to the 2nd dorsal.

Number of anal finlets: counted in the same manner as the dorsal finlets.

Number of gill rakers: the number of anterior rakers on the most anterior gill arch on the left side of the fish. The counts of the rakers on the two arms of the arch are kept separate.

Liver: observations on markings, shape, weight.

d) BIOMETRIC MEASUREMENTS ON SHARKS

Distance from the tip of the snout to the first branchial fissure.

Snout to insertion of 1st dorsal.

Snout to insertion of 2nd dorsal.

Snout to insertion of anal.

Snout to insertion of ventrals.

Greatest depth.

Length pectoral.

Height of the 1st dorsal: note if there is a spine and its length.

Height of the 2nd dorsal: note as before.

Length of the dorsal lobe of the caudal fin.

Length of the ventral lobe of the caudal fin.

Greatest width of the caudal peduncle at keels.

Number of branchial fissures.

Shape of the snout: design.

Shape of the teeth: central upper maxillary
lateral upper maxillary
central under maxillary
lateral under maxillary

Distance between the nostrils.

Distance from the tip of the snout and the midst of the line joining the nostrils.

Liver: observations on colour and weight.

Denticles of the skin: observed under a magnifier and sketch form and disposition.

2.4 WEIGHING

We are concerned here only with weighing individual species for biological purposes, and not at all with weighing catches. The weight of individual fish is required chiefly for the determination of length-weight relation and condition factors. Weighing of separate organs (e.g. stomach, gonads) is made for various purposes (e.g. for determination of the amount of food taken, determination of number of eggs, etc.).

The only reliable transportable instruments are steelyards and spring balances. Simple transportable laboratory balances are also useful but the weights with which they are used render them slow in use. Shop balances can also be used in fish markets if a stable base can be provided and care is taken of them in transport. Spring balances are sensitive to temperature changes and many other factors, but small pocket size spring balances in various ranges, (e.g. 0 - 1 kg. and 0 - 10 kg.), are useful for rough measurements and should be carried on all trips.

The wetness of the fish should be noted when weighing must have high accuracy. The biologist must decide on the attention to be given to the effect of differences in amount of stomach contents and in development of gonads. For some work these organs must be weighed separately.

It is often necessary to weigh butchered fish - i.e. fish whose viscera and, or heads have been removed after capture. In most cases it is desirable to convert the weight of butchered fish to the original live weight. Several conversion tables have been established, for this purpose, by bulk of species, differently butchered and for different size of the same species. These conversion tables will be given in the Laboratory Manual.

2.5 FIELD EXAMINATION OF GONADS

The state of maturity of fish can be determined in field examination. This is usually done by exposing the gonads by opening the ventral cavity.

There are several criteria for determination of maturity stages, which vary from one group of species to another. However, the following classification of maturity stages can be used for most species (Naier, from Bückmann, 1929).

Stage I – *Virgin:* Very small sexual organs close under the vertebral column. Testis and ovary transparent, colourless to grey. Eggs invisible to naked eye.

Stage II – *Maturing virgin* and *recovering spent:* Testis and ovary translucent, grey-red. Length half, or slightly more than half, the length of ventral cavity. Single eggs can be seen with magnifying glass.

Stage III – *Developed:* Testis reddish-white. No milt-drops appear under pressure. Ovary orange reddish. Eggs clearly discernible; opaque. Testis and ovary occupy about two-thirds of central cavity.

Stage IV – *Developing:* Testis and ovaries opaque, reddish with blood capillaries. Occupy about half of ventral cavity. Eggs visible to the eye as whitish granular.

Stage V – *Gravid:* Sexual organs filling ventral cavity. Testis white, drops of milt fall with pressure. Eggs completely round, some already translucent and ripe.

Stage VI – *Spawning:* Roe and milt run with slight pressure. Most eggs translucent with few opaque eggs left in ovary.

Stage VII – *Spent:* Not yet fully empty. No opaque eggs left in ovary.

Stage VIII – *Resting:* Testis and ovary empty, red. A few eggs in the state of reabsorption.

Note: Doubtful cases are indicated by referring to two stages, e.g. VIII - II, I - II, etc. Stages VII and VIII are sometimes grouped together as stage VII spent.

The gonads should be weighed in fresh condition, because their weight may change considerably when preserved. The counting of eggs can however be done on preserved material. When counting eggs in the field, measure the total displacement volume of the eggs from the ovary in a graduated cylinder. Remove the eggs from the water and count some of them. Measure the displacement volume of the counted eggs and compute the number as follows:-

$$\text{Number of eggs} = \frac{\text{Total volume of eggs} \times \text{Number of eggs counted}}{\text{Volume of the counted eggs}}$$

The diameter of fresh eggs may be measured by placing 10 - 50 eggs in a row, measuring the total length of the row, and dividing by the number in the row.

2.6 FIELD EXAMINATION OF STOMACHS

In a field examination of stomachs the following preliminary notations are used:-

a) *Degree of fullness* – Full, half full, nearly empty, empty.

b) *Degree of digestion* – Fresh, half digested, digested.

c) *Type of food in the stomach* – Give the identifiable species or groups of species and estimate their relative abundance (e.g. fish larvae 50%; Euphausids 25%; unidentified 25%).

d) *Stage of the fish* (mainly applicable for Clupeoids) –

1° – LEAN – no traces of fat in the digestive tube.

2° – NOT VERY FAT – a string of fat not thicker than 1 mm along the digestive tube.

3° – FAT – a string of fat thicker than 1 mm, but not enveloping the intestine completely.

4° – VERY FAT – the digestive tube is completely enveloped by the fat.

Exact volumetric measurements of stomach contents and detailed identification of food species found in the stomach are usually carried out in the laboratory.

2.7 OBSERVATIONS ON FISH DISEASES AND MORTALITY

All fish which have symptoms of disease should be preserved for laboratory study. This is especially necessary if abnormal mortality of fish is observed. Before preservation, a field examination and description should be made. This examination should include notation of: (1) Gills (colour, whether gill lock and mouth are open, presence of parasites, algal growth or mud on gills, etc.); (2) Colour of the fish body, discolouration, etc.; (3) External damage of the body; (4) Discolouration or malformation of liver, stomach, etc.

Only dying or recently dead fish may be preserved for further laboratory study.

When mass mortality of fish is observed, the environment should be described in fullest possible detail. Note especially the winds and currents at the time of the observation and for the previous days. If proper hydrographic survey work cannot be undertaken water should be sampled; at each station three 1-litre bottles of water should be taken, one unpreserved, one preserved with hydrocloric acid (about 7.5 ml; 12 normal HCl per litre), and the other with formalin to get approximately a 2% solution of formaldeyde. It is advisable, if possible, to take samples at several places and at several depths, especially "upcurrent" and "upwind" of the place where the dead fish occur. Plankton samples should also be collected. The samples should be sent to the laboratory for analysis as soon as possible.

2.8 TAGGING OF FISH

The purpose of tagging operations is to obtain information on

1) Migrations

2) Fishing mortality

3) Growth

The planning of these operations involves decisions on size range of fish to be tagged, places and times of tagging, numbers of fish to be tagged at each tagging occasion and in the entire programme, and methods to be adopted to obtain delivery of recovered tags and tagged fish. These decisions are made in the light of what is already known of the biology of the species under investigation, and with reference to the problems to be studied and to technical aspects of the operations. The technical questions concern the choice of tag, the methods of capturing, handling and releasing of the fish. The whole subject will be dealt with in detail in a special manual.

2.9 INVESTIGATIONS ON FISH EGGS AND LARVAE

Fish eggs and larvae are collected together with the plankton by the methods described in Chapter 5.1.

Buoyant eggs of coastal spawning fish are often washed ashore and can be collected on tide marks or in wave wash. Eggs on the bottom are gathered

with bottom egg-nets which are equipped with a scraper which scratches the eggs loose and leads them into the bag; or a special highspeed trawl is used, which also catches small vagile benthos organisms, such as Harpacticoids.

2.10 OBSERVATIONS ON BEHAVIOUR AND DISTRIBUTION

Although direct observation of the behaviour of fish in its environment has become more practicable, most conclusions on fish behaviour are drawn from a variety of observations on their occurrence and on prevailing environmental conditions. Certain types of observations should be made systematically in the course of field work, and must be carefully recorded.

(a) Schools of fish observed close to the surface must always be recorded, giving the exact position, the estimation of the size of school, its probable species, the behaviour (such as jumping, etc.) and the direction of the movement. Furthermore, the prevailing sea conditions must be recorded simultaneously (state of the sea, colour, etc.).

(b) The direction of approach of fish to gill-nets should be recorded together with the direction of the layed net and the direction of the currents.

(c) The depth occurrence of the fish in gill-nets and on trolled longlines should be recorded if possible (e.g. if fish are caught in gill nets mainly on the upper or lower part etc.).

(d) Response of pelagic fish to bait should be recorded.

(e) Degree of liveliness of fish caught with trawls and traps should be noted if differing from normal. Also other abnormal conditions of catch could be noted (e.g. abnormally high vomiting, etc.).

Good information can be obtained from echosounder (and asdic) observations, and precise correlation of location and behaviour with various environmental features can be obtained.

2.11 SOME REFERENCES ON FISHERIES BIOLOGY METHODS

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2.12 EXPLANATION OF TERMS IN SECTION 2

Caliper – A graduated rod or rule with one fixed and one sliding jaw.

Carapace – A bony or horny case or shield covering the back or part of the back of certain animals.

Caudal fin – Tail fin.

Condylus – Knuckle, joint.

Cube root – A root of a tropical American plant furnishing rotenone.

Denticle – A small tooth.

Dorsal – Pertaining to, or situated near or on the back.

Face mask – Mask used in diving in shallow water.

Iris – The opaque contractile diaphragm perforated by the pupil and forming the coloured portion of the eye.

Lateral – Of or pertaining to the side.

Maxillary – Of, pertaining to or designating a jaw.

Otolith – Ear stone, a calcareous concretion in the internal ear.

Pectoral – Of, pertaining to, situated or occurring in or on the breast or chest.

Peduncle – A stem or stalk.

Rostrum – A part suggesting an animal's beak.

Ventral – Designating, pertaining to or situated on the belly (or lower surface of the body).

Form 2

Fishing Log

a) Vessel ..... b) Journal No. ..... c) Date .. ....
d) Station No. ..... e) Locality (area) . . ..
f) Lat. ..... g) Long. . . . .

1.1 1.2
1. Depth (of water) ..... Nature of bottom . . . .

2.1 2.2
Weather ..... Wind . . ..
2.3 2.4 2.5
2. Sea ..... Colour ..... Current .....
2.6 2.7
Water Temperature ..... Depth of thermocline .....
2.8 2.9
Air Temperature ..... Barometer .....

3.1
Gear type . . . . . .
3.2 3.3 3.4
3. Wire out Wire angle Speed of vessel ... .
3.5
Direction of haul . . . . . .

4.1 4.2
Gear-setting started ..... Gear out .....
4. Time:
4.3 4.4
Hauling-in started . . Hauling-in finished ....

5.1 5.2
Depth of capture . . How fish located .. ..
5.3
Weight of total catch .....
5.4 5.5
5. Principal species retained Principal species discarded .....
and sizes . . . . . and sizes . . . .
. . . . . .
5.6
Samples taken .....

---

6. Remarks . . . . . .
....

NOTES ON FORM 2: FISHING LOG

e) – Also give the name or general description (e.g. Wadge Bank).

1.2 – If fishing for demersal fish give the type of bottom (and/or type of coast).

2.1 – Give code.

2.2 – Give direction and force, code.

2.3 – Give code.

2.4 – Give in Forel scale.

2.5 – Give direction (and speed if observed).

2.6 – Also give the depths if observed at several depths with reversing thermometer.

2.7 – As ascertained from BT data.

3.1 – Give type, dimension and essential mesh sizes, bait if used, etc. For night-light fishing give the depth of light and strength of light.

3.2/3.3 – Give the amount of wire out, wire angle and speed and direction
3.4/3.5 of vessel when trawling.

4 – Give times so that actual hauling time can be computed.

5.2 – E.g. echo-sounder, conventional ground, visual observation of schools, experimental run.

5.3 – Give the number of baskets, etc. and their approximate weights, (include discarded).

5.4/5.6 – Give all organisms present in the disregarded catch on commercial vessels and estimate their amount.

5.7 – Indicate weather measurements made, samples preserved, etc.

6 – E.g. damage to gear, behaviour of fish, etc.

At 5.4 and 5.5 a form in use would have more space, appropriate to the usual diversity of catch retained and discarded.

Form 3

Morphometry and Life History Data Sheet

a) Species ..... b) Date			c) Measured by		
1 Locality					
2 Gear of capture					
3 Weight					
4 Total length					
5 Fork length					
6 Head length					
7 Snout to ins. 1st D					
8 Snout to ins. 2nd D					
9 Snout to ins. anal					
10 Snout to ins. ventral					
11 Greatest body depth					
12 Diam. of eye					
13 No. gill rakers					
14 Colour					
15 Stomach content { 15.1 Volume					
15.2 Composition					
16 Sex					
17 Degree of maturity					
18 Preserved: { Scales					
Gonads					
Vertebrae					
Operculum					
Entire specimen ..					
Other (specify)					

19 Remarks: – _____

NOTES ON FORM 3: MORPHOMETRY AND LIFE HISTORY DATA SHEET

This sheet is generally used for single specimens of large species but can also be used with small modifications for groups of specimens sampled. The sheet presented can be used for measurement of five specimens. The methods of measurement are described in Section 3. The measurements Snout to ins. 1st D *et seq.* are the lengths from the snout to the insertion of the respective fins.

14 – Describe the colour of fish if necessary (e.g. by exotic species).

15 – Give the volume of food in stomach and briefly describe its composition.

17 – Maturity scale.

18 – Indicate the preservations made and give their serial numbers.

19 – Make notes on such factors as depth of water, proximity of land, depth of water, where caught, etc.

Form 4

Measurements of Fish

a) *Species* . . . . . .

b) *Date* . . . . c) *Locality* . . . . . d) *Sheet No* . . . . .

e) *Vessel, Cruise, Station, etc.* . . . . . .

f) *Gear of capture* . . . . . .

1						2				
	0									
	1									
	2									
	3									
	4									
	5									
	6									
	7									
	8									
	9									
	0									
	1									
	2									
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	7									
	8									
	9									
	0									
	1									
	2									
	3									
	4									
	5									
	6									
	7									
	8									
	9									
	0									

3. *Remarks* . . . . . .

NOTES ON FORM 4: MEASUREMENT OF FISH

This form is useful for measurement of many specimens of the same species.

c – Give the locality of measurement.

e – Give the name of the vessel and the locality of capture.

1 – Use column one for lengths. Last digits of the length can be printed, as shown, and the other digits should be put to suit the length range of fish to be measured.

2 – In the columns tick the number of fish at each length (e.g. 5 ticks in every column) or use this column for weights if weighing of individual fish is done.

3 – Indicate the kind of length measured (e.g. total length, fork length, etc). Give also remarks on the conditions of measurement and the condition of fish.

Sometimes filing cards are used for recording fish measurements. One side of the card contains usually the following data: (a) species; (b) area; (c) depth; (d) gear; (e) vessel; (f) locality of landing; (g) locality of catch; (h) depth of water; (i) fishing effort; (j) total catch by species, etc. The other side is made for recording lengths as in Form 3.

Form 5 Labelling of Collections

(1) The labels should be made of suitable material (e.g. linen) so that they can be put into the preservative together with the specimens. The writing on these labels should be done with an indelible pencil. Gummed labels should not be used outside the jars. The labels should be of the tie-on variety. An example of the data needed on a label follows:-

Index ..... *Species* .....

Date ..... *Time* .....

Locality .....

Measures .....

Gear ..... *Depth* .....

Observer, Collector ..... *Vessel and Station No* .....

Log .....

Index – indicate with proper codes whether it is plankton, fish stomach.

Measures – e.g. displacement volume of plankton and total length of fish; always indicate what has been measured.

Gear – the gear or method of capture.

Log – indicate the logs in which notes on preservation are recorded

When systematic extended collecting is being done it is better to identify each specimen with a log of suitable material on which is embossed a number. A specimen tag is then maintained, providing for the entry opposite each number of the detailed information suggested above for labels.

Section 3

FIELD OBSERVATIONS ON FISHING OPERATIONS

3.0 INTRODUCTION

Whilst a very large part of the data on which fishery biologists work consists of statistics of catch and of effort expended in taking it, the biologists interest in fishing operations does not cease with the examination of such statistics. In the first place a fishery biologist must, with his technologist and economist colleagues, examine evidence on the nature of fishing effort, especially with regard to such characteristics as selectivity and efficiency. In the second place much can be learned about the behaviour of fish from the direct study of relations between the fish and the fishing gear. Fishing gears and the methods of their use have been devised, especially in traditional fisheries, from considerable careful observation of fish behaviour, and hence a report of an observation of a particular type of gear in use can of itself be exceedingly informative with regard to resources in the area of observation. In the third place a biologist may gather much information concerning the stocks he is studying by gathering together the observations of fishermen. For these and other reasons we include here some guides on the field work that may be done to gather such information.

3.1 IDENTIFICATION OF FISHING OPERATIONS, METHODS AND GEARS

A principal requirement of reports of observations on fishing is that there should be correct identification and description of the gears seen, and the methods by which they are used.

Fishing Operations: this term signifies all operations in moving to and from fishing grounds, fish-searching and actual fishing. In reporting on operations in a particular locality a full account should be given of each phase of these operations, as follows:-

1) Movement to and from fishing grounds: distance travelled, time of travel, whether trip is made by fishing vessel unaided or with mother-ship; nature of navigational method.

2) Fish searching: whether aided by instruments and if so of what type; the signs looked for, such as water depth, type of bottom, current or other features of the sea, birds.

3) Fishing method: identify the method and describe any unfamiliar features of it. Methods fall into five principal classes:

   a) *Collect:* picking up molluscs, sponges, etc. and dredging,

   b) *Kill and retain, simultaneously:* with weapons and hunting animals,

   c) *Kill and then collect:* using poisons, explosives, and electricity,

   d) *Attract, then kill and hold:* with baits and hook and line, and some set gears,

   e) *Capture, then kill:* with traps and nets.

4) Gear : the following classification, with the diagrams, will assist in identification of gears.

This classification signifies primarily the manner in which the gear itself operates against the fish, as operated or directed by the fishermen. The five main headings show the principal divisions in this sense of operational character whilst the various levels of subdivision indicate structural and operational features that serve this relation between fish and gear.

1. Gear for simple collection
   - 1.1 Baskets and other simple containers
   - 1.2 Dredges
   - 1.3 Dip nets
2. Gear used for simultaneous killing and retention
   - 2.1 Weapons thrust, thrown or projected with retention by hand or line
     - 2.11 Hand instruments
       - 2.111 Lances
       - 2.112 Spears
       - 2.113 Clamps
     - 2.12 Bow and arrow
     - 2.13 Harpoons
       - 2.31 Hand harpoons
       - 2.32 Rifle harpoons
       - 2.33 Gun harpoons
     - 2.14 Rip hooks
     - 2.15 Gaffs

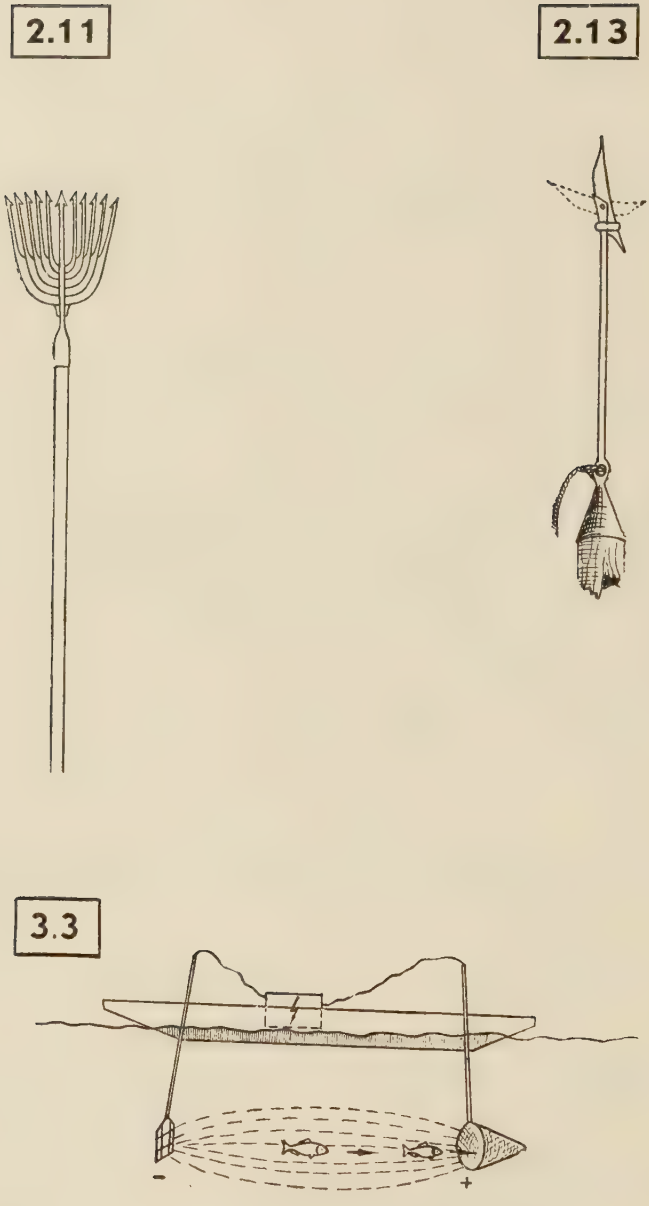
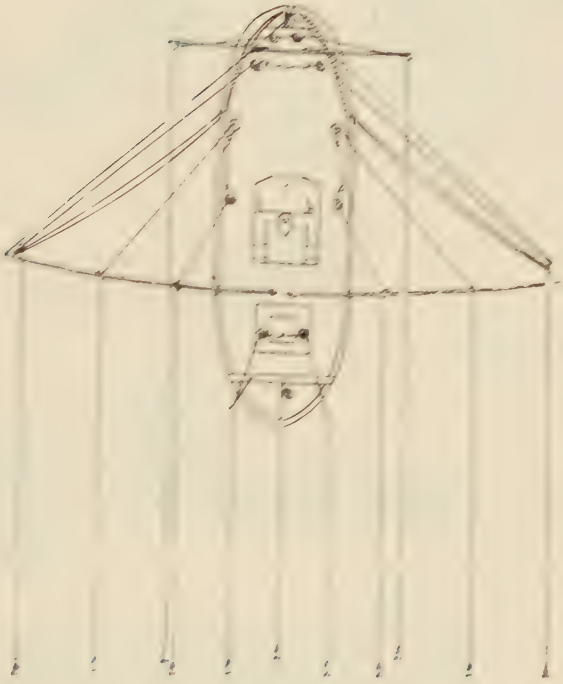


Figure 7. - Types of fishing gears
(for explanation see classification pp. 57-68)

4.122113



4.122222

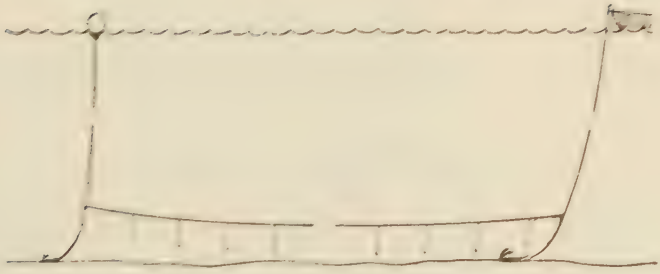


Figure 7 (cont.) - Types of fishing gears

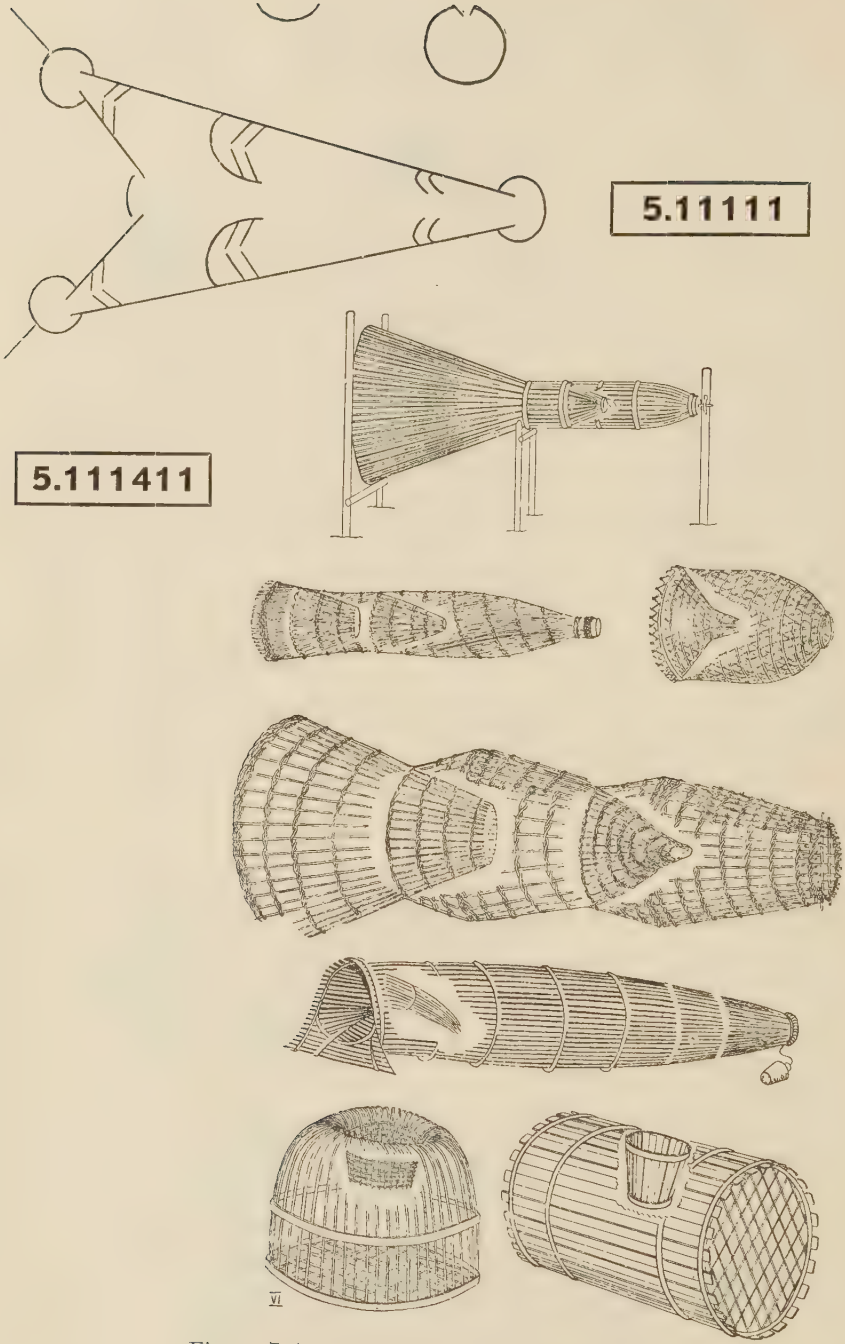


Figure 7 (cont.) - Types of fishing gears

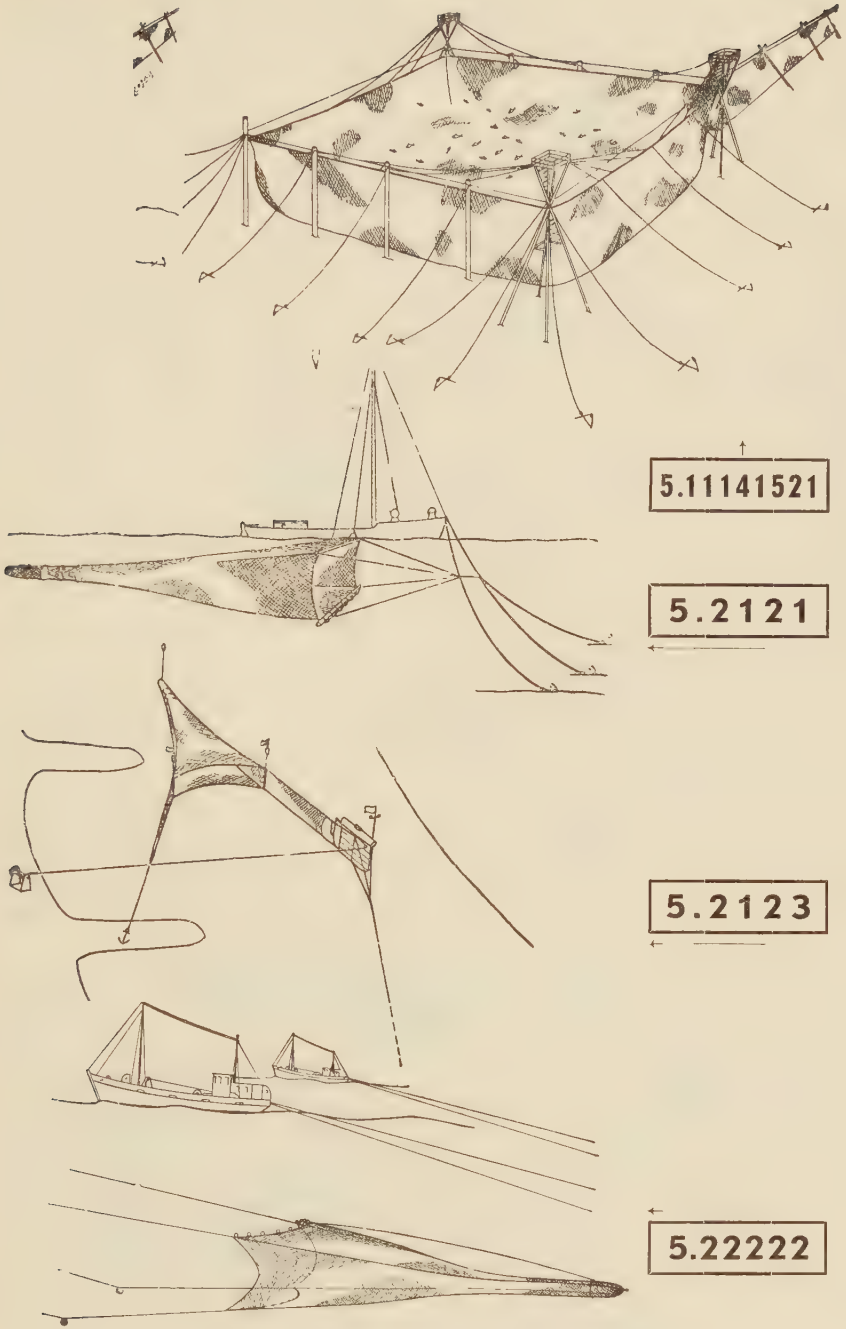
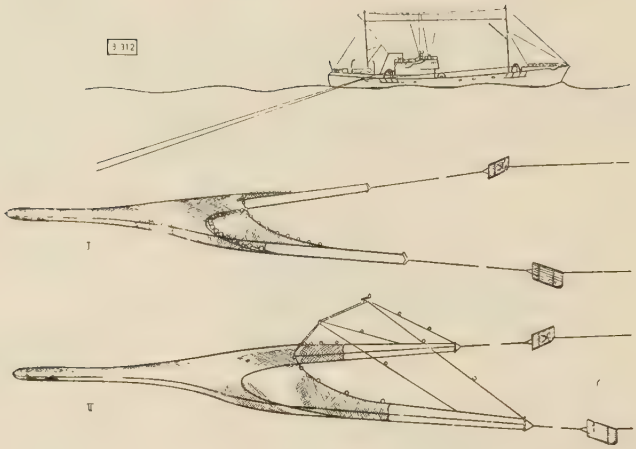


Figure 7 (cont.) - Types of fishing gears

5.22212



5.2322

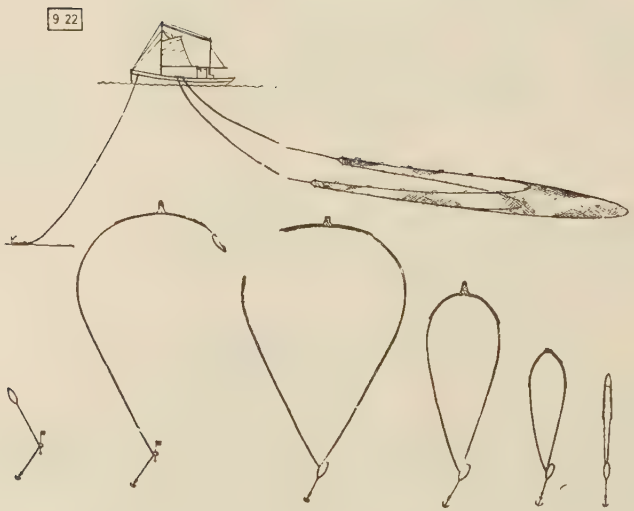


Figure 7 (cont.) - Types of fishing gears

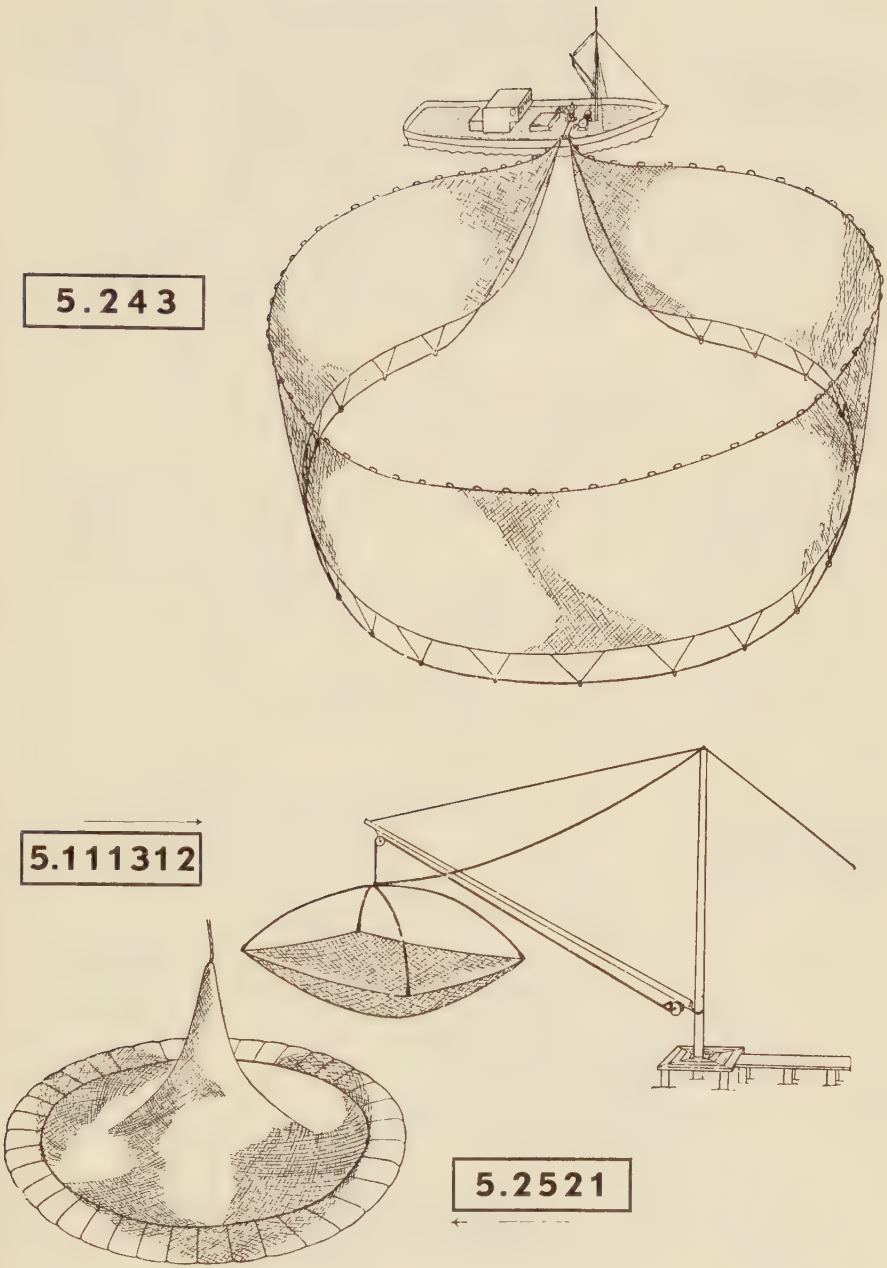


Figure 7 (cont.) - Types of fishing gears

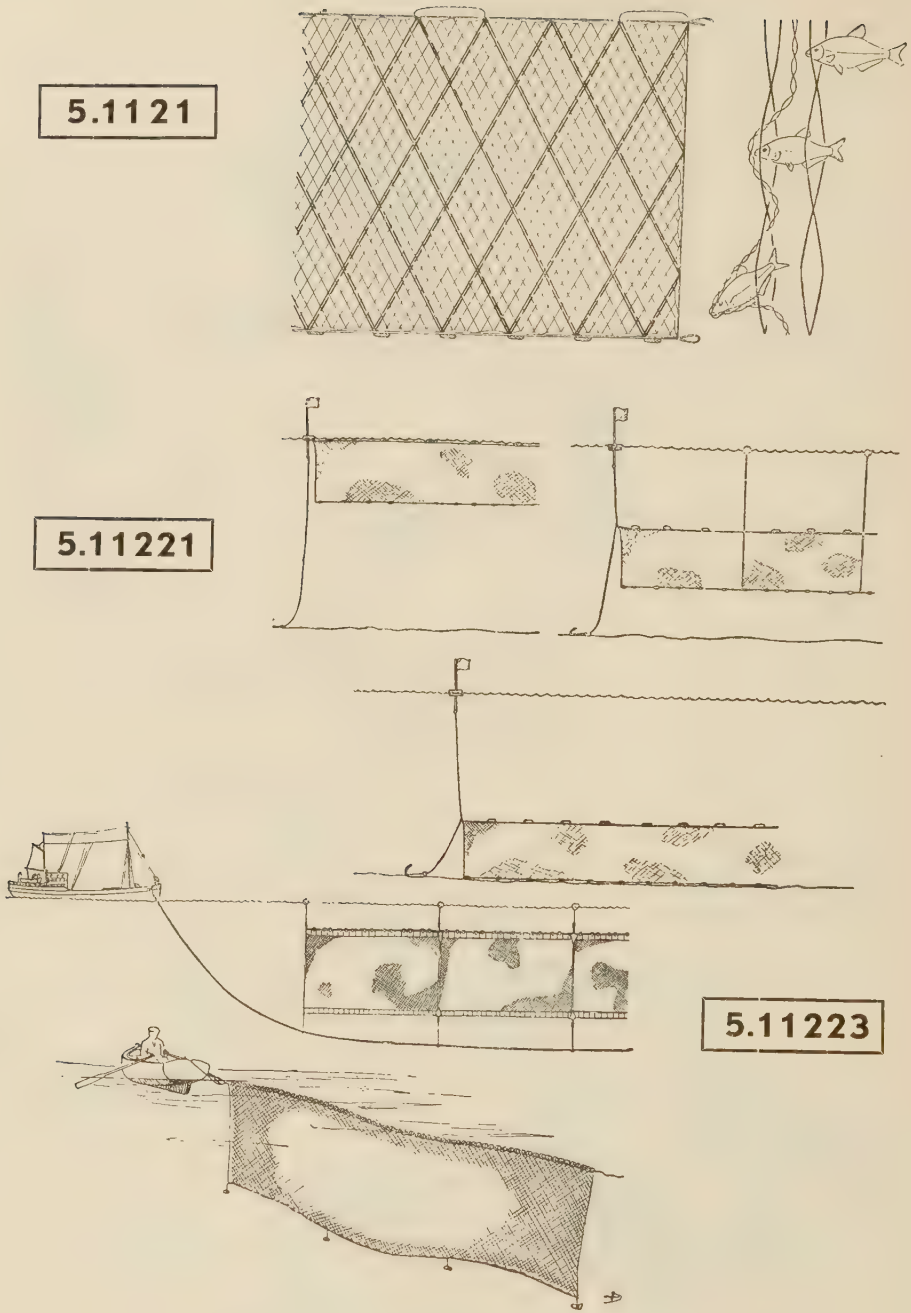


Figure 7 (cont.) - Types of fishing gears

2.2 Hunting animals

2.21 Cormorants

2.22 Sucker fish

2.23 Otters

2.24 Dogs

3. Gears (and materials) used in killing fish which are afterwards collected

3.1 Striking weapons

3.2 Poisons

3.21 Released in water

3.22 On data (blow pipes)

3.3 Electrical apparatus

3.4 Explosives

3.41 Thrown explosives

3.42 Rifles

3.5 Weapons thrust, thrown or projected without retention (divide as for 2.1)

4. Gears used in killing and holding fish that have been attracted

4.1 Lines and hooks

4.11 Without hooks

4.12 With hooks

4.121 Gorge

4.122 Curved hooks

4.1221 Watched

4.12211 Hand-angling

4.122111 Handline

4.122112 Rod

4.122113 Troll line

4.1222 Unwatched

4.12221 Floated line, drift-longline

4.12222 Anchored

4.122221 Standing line

4.122222 Longline, set longline

5. Gears used to capture fish which are then killed and retained.

5.1 Stationary gears (with no horizontal movement, fish being brought to the gear by their own movement in response to natural forces, e.g. currents, or to attraction, e.g. light, or reaction to some driving influence, e.g. sound).

5.11 Passive stationary gears

5.111 Traps

5.1111 Barriers

5.11111 Fish-hedges

5.11112 Box traps

5.1112 Fish corral, fish weir

5.1113 True traps

5.11131 Gravity traps

5.11132 Snares

5 111321 Wire-snares

5.111322 Rope-snares

5.111323 Stock-snares

5.11133 Whippy bough trap

5.11134 Torsion shutter trap

5.1114 Baskets

5.11141 Grounds baskets

5.111411 Fish pots

5.111412 Wire baskets

5.111413 Fyke net

5.1114131 Braced bag

5.1114132 Fyke net with rings

5.11314 Creels

5.111415 Trap net, pound traps

5.1114151 Trap nets with rings

5.1114152 Box nets

5.11141521 Stake nets

5.11141522 Fixed nets

5.11142 Buoyed trap

5.1115 Aerial traps, jumping fish traps

5.11151 Verandah net

5.11152 Raft trap

5.11153 Boat trap

5.11154 Box trap

5.112 Gill nets and tangle nets

5.1121 Trammel nets

5.1122 Gillnets

5.11221 Set gillnets

5.11222 Floating gillnets

5.11223 Drift nets

5.1123 Tangle nets

5.113 Active stationary gears, with vertical movement for capture

5.1131 Lift nets

5.111311 Hand lift nets

5.111312 Stationed lift nets

5.111313 Boat lift nets

5.111314 Water wheels

5.2 Moving Gears, with horizontal action

5.21 Bag nets with fixed mouth

5.211 Scoop, dip net

5.2111 Skimming net

5.2112 Push net

5.2113 Dragged bag nets with fixed mouth

5.212 Gape nets

5.2121 Swing nets (stow nets) on stakes

5.2122 Swing nets (stow nets) on anchors

5.2123 Otter-board stow net

5.22 Dragged gears

5.221 Sweep nets

5.2211 Single walled

5.2212 Triple walled

5.222 Trawl

5.2221 Bottom trawl

5.22211 Beam trawl

5.22212 Otter trawl

5.22213 Pareja

5.2222 Floating trawl

5.22221 Surface floating trawl

5.22222 Mid-water floating trawl

5.23 Seines

5.231 Without bag

5.232 With bag

5.2321 Beach seine

5.2322 Boat seine

5.24 Surrounding nets

5.241 Barrier nets

5.242 Spiral nets

5.243 Ring nets, purse seine

5.25 Falling nets

5.251 Lantern nets, cover pots

5.252 Cast nets

5.2521 Hand cast nets

5.2522 Cast nets from gallows or sheerlegs

5.2523 Cast nets from boats

3.2 COLLECTION OF INFORMATION ON FISHING OPERATIONS

Fishermen are a source of circumstantial information that can prove of great value in some stages of research programmes. Principally this information relates to the location and magnitude of resources, but often extends to behaviour. Form 6 illustrates the kind of questionnaire that can be used as a check-list of questions which may be addressed to fishermen and, with its notes, indicates the manner of recording the replies given. Care must be taken, in framing questions, to avoid "leading" the person being questioned into giving an answer which he thinks the enquirer wants to hear or which he believes will serve the fishermen's own purposes.

Questionnaires of the kind illustrated in Form 6 should be used for unit fisheries and with regard to matters of which an informant can claim personal experience. Unit fisheries are usually designated by a name signifying the fishing grounds, or the species caught or the type of gear used, or the type of craft from which the fishing is conducted; sometimes a combination of these features is used. The main divisions for fishing grounds are as follows:

Inland

- Cultivated stocks in ponds etc.
- Wild stocks in rivers, lakes reservoirs, etc.
- Estuarine fisheries

Marine

- On-shore (beach fisheries etc.)
- Near-shore or neritic
- Off-shore
  - Pelagic
  - Mid-water
  - Demersal

Form 6: Questionnaire for Interviewing Fishermen

1. THE INTERVIEW

1.1 Interviewer's name .....

1.2 Date of interview .....

1.3 Plans .....

2. INFORMANT

2.1 Informant's name .....

2.2 Address .....

2.3 Occupation ..... skipper
master fisherman
member of crew
other

2.4 Type of fishing in which informant engages:

2.5 Fishing unit in which informant works:

3. THE UNIT FISHERY ON WHICH INFORMANT FURNISHES INFORMATION

3.1 Name of fishery

3.2 Fishing Grounds

3.21 Location:

3.22 Distance from port or landing place:

3.23 Nature of grounds:

3.24 Sea conditions usually encountered on grounds at fishing time:

3.3 Fishing Operations

3.31 Season:

3.32 Operating programme:

3.33 Amount of time sailing to grounds:

3.34 Fish searching methods:

3.35 Fishing method:

3.36 Fishing gear:

3.37 Inboard handling of fish:

3.4 The Fish and the Catch

3.41 Usual composition of catch:

3.42 Seasonal variations in composition and size of catch:

3.43 Behaviour of the fish (migrations and schooling):

3.44 Spawning (season, place):

3.45 Feeding:

4. GENERAL OBSERVATIONS:

NOTES ON FORM 6: QUESTIONNAIRE FOR INTERVIEWING FISHERMEN

Use one form for each unit fishery on which informant will give information; that is, when an informant can give information on two or more unit fisheries, use two or more forms.

2.4 Give the name of the type of fishing operations in which informant says he is engaged; if he is engaged seasonally in different fisheries, give both and if possible the proportions of time spent in each.

2.5 Give name of boat or other identification.

3.23 This applies primarily to bottom or foreshore; muddy, sandy, rocky, etc.

3.32 Give average duration of trips; times of departure; turn around time.

3.34 If aids to fish detection are used report them: note also signs (birds, water colour, etc.) looked for.

3.37 Report whether the fish are treated (gutted etc.) on board and how they are stored.

Section 4

OBSERVATIONS ON THE PHYSICAL AND CHEMICAL ENVIRONMENT

(Meteorology and Oceanography)

4.0 INTRODUCTION

The observations for which techniques are described here are among the complementary observations discussed in Section 1.1.2. It is to be emphasized that the plan for observations for this kind is to be made in accordance with the overall plan for the research of which the field work is part; hence it must not be thought that all the techniques described here are to be used during each field trip.

4.1 THE ATMOSPHERE. METEOROLOGICAL OBSERVATIONS

Meteorological observations should be made during field work in fisheries biology because of the direct and indirect influences exerted by meteorological elements on fish stocks. The state of the weather at a particular time exercises a considerable influence on the behaviour of pelagic stocks in surface waters at that time. The intensity of light incidence and the duration of daylight in each 24 hours plays a considerable part in determining the level of basic production by phytoplankton. The effect of winds in causing water movements is a primary factor in determination of the distribution of nutrient salts. Records of weather conditions are therefore necessary to the biologist directly, and are indirectly necessary from the use that can be made of them by the oceanographers. Detailed instructions on meteorological observational practices are laid down in WMO Publ. No. 8, especially in Chapter 10. Port-meteorological officers in larger ports have further local information, and can check instruments and issue meteorological logbooks. It is in the interest of every observer to make himself familiar with the use and care of his instruments before undertaking routine observations.

Meteorological readings are recorded on an appropriate data sheet, a form for which is appended at the end of the Chapter. When working in small boats near the coast and/or lacking some instruments, short log sheets are used omitting some data. Only the values obtained during the moment of observation or measurement should be recorded; such values generally have a close relation with the average values for an hour or more preceding the moment when they are taken. Some rules are provided in weather manuals to guide the choice of times and circumstances of meteorological observations, so that these should have maximum representativeness.

Synoptic meteorological observations should be taken at established standard hours (0000, 0600, 1200 and 1800, with intermediate observations at 0300, 0900 and 1500 G.M.T.). Observations for special purposes can be taken at any time and can be recorded in the local time.

4.1.1 Wind

Wind speed and direction may be determined either by visual estimates or with anemometers.

DIRECTION

Wind direction offshore can be ascertained by observing the motion of true wind waves and ripples, but *not* of swell waves since these are caused by wind in some distant area. This method is inaccurate for position close to the shore because of shelter effects and the reflection of waves; and other means must be used, such as observation of the movement of flags and smoke.

Wind direction should be recorded in tens of degrees from true North(01-36).

FORCE (SPEED)

Wind speed is recorded by reference to the Beaufort scale in conjunction with Captain Petersen's sea and coastal criterion tables, (Tables 1 and 2), or is measured with anemometers When anemometer observations are taken from a moving ship, it is advisable to draw a simple vector diagram to compute the true wind graphically from observations of the relative wind and the ship's speed and course (Fig. 8). Wind speed, if measured by anemometers, should be recorded in knots or meters per second. Anemo-tachometers show the measured wind speed directly on the scale. With simple anemometers it is necessary to divide the measured windway by the number of observation seconds.

BAROMETRIC PRESSURE

Pressure is measured either with a mercury barometer or with a precision aneroid. In the case of mercury barometers the "pumping" effect should be allowed for when a reading is made. This characteristic and the amount of the pressure tendency are obtained with a barograph. Pressure and tendency should be recorded in millibars (See Table 3). For synoptic reports the pressure should be reduced to the gravity at 45° latitude, sea level and O°C, but for fisheries purposes such correction may be unnecessary.

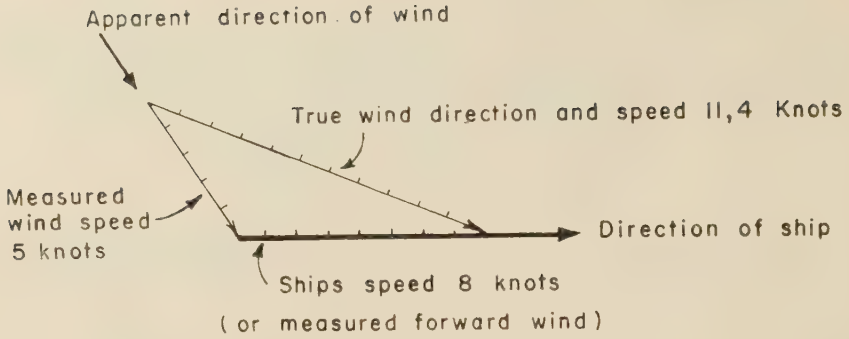


Figure 8. - Example of how to obtain true wind speed

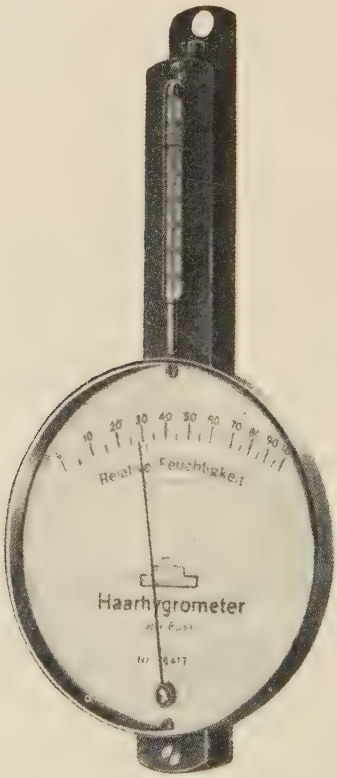


Figure 9. - Hair hygrometer

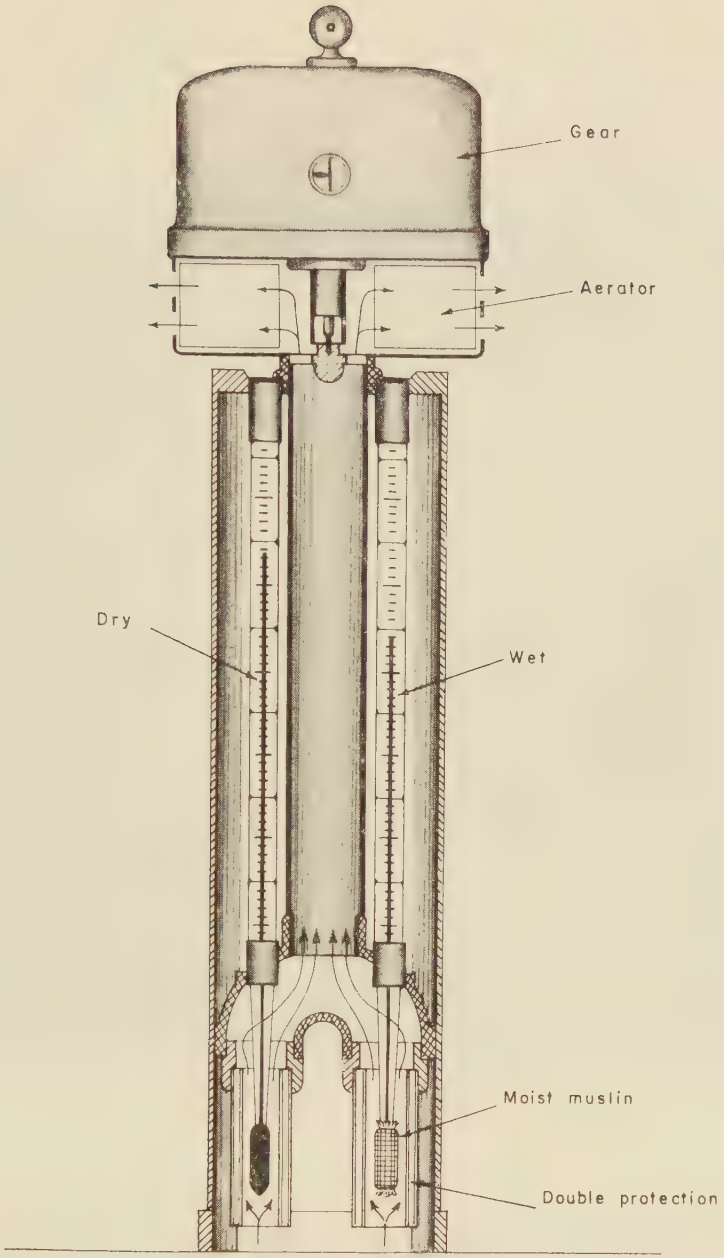


Figure 10. - Assmann's aspiration psychrometer

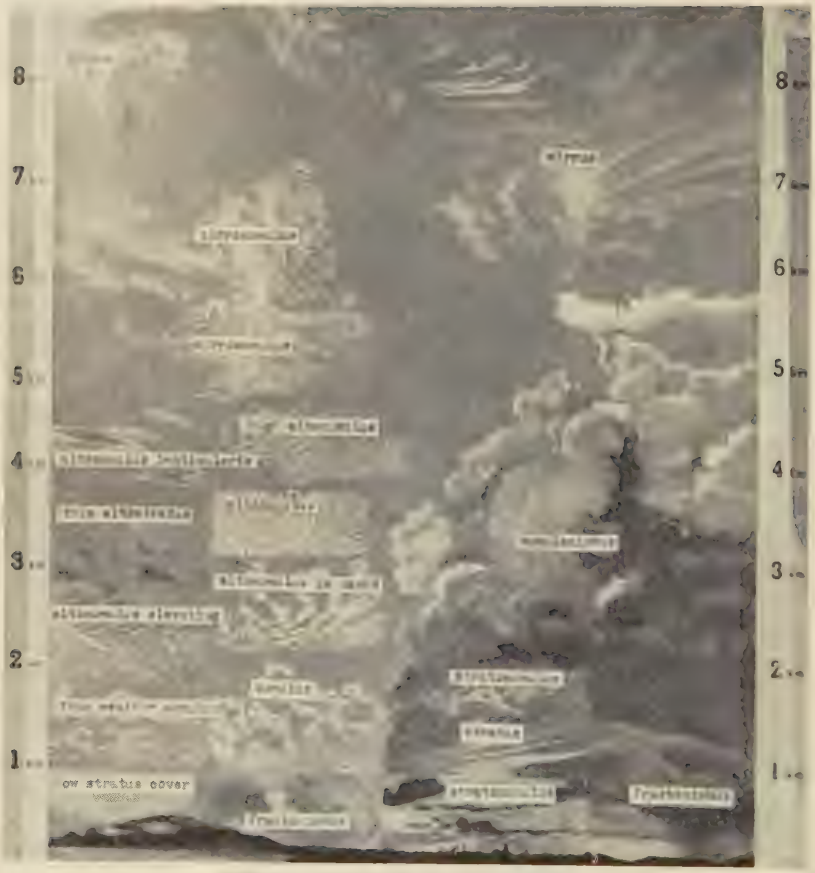


Figure 11. - Cloud forms

4.1.2 Air Temperature

To obtain a representative measure of air temperature, thermometers should be protected from the sun's radiation both that direct from the sky and that reflected from surrounding objects, and at the same time they should be adequately ventilated. Mounted thermometers on ships are generally unsatisfactory. For routine observations there is no advantage in using thermometers which have very rapid response, since air temperature continually fluctuates a degree or two within a few seconds. Conventional thermometers should be read as rapidly as is consistent with accuracy in order to avoid changes of temperature due, for example, to breathing on the thermometer. At sea temperature is usually measured with a psychrometer (Fig. 10) of which the dry thermometer records the air temperature. (See further under Humidity measurements.)

There are several types of thermograph in use. The requirements for and the handling of these instruments are described in WMO Publ. No 8. It is usually sufficient to record the air temperature with an accuracy of $\pm$ 0.5°F or $\pm$ 0.25°C. A Fahrenheit to Centigrade conversion table is given in the appendix (Table 4).

4.1.3 Humidity

Air humidity is measured either with hygrometers (Fig. 9) or psychrometers (Fig. 10). The latter (the so-called wet and dry bulb thermometer) is the commonest form in use at sea. Psychrometers must be well exposed in a stream of air fresh from the sea. The wet bulb is moistened with distilled water. If the ventilation of the psychrometer is operated manually, the thermometer must be read as soon as possible after ventilation has stopped. Psychrometers operated electrically (with battery) can be read during ventilation.

4.1.4 Precipitation

There are difficulties in the measurement of the amount of precipitation at sea and there are no satisfactory rain gauges for use on small vessels. Therefore, it is sufficient to record the kind and intensity of precipitation at the hour of observation and the weather of the previous hour by using the symbols in appendix (Table 5 and Fig. 11).

4.1.5. Clouds and weather

The form, amount and direction of movement of clouds observed at sea should be recorded. The form can be noted by use of a cloud atlas. An abridged illustration of cloud forms is shown in Fig. 11 and the code for cloud types in Table 6. The amount of clouds should be estimated in 1/8 of the

sky, according to the code in Table 7. "Traces" of cloud should be included under scale No. 1 which should be used for amounts up to 1/8. "Overcast but with openings" should be included under scale No. 7 . Direction of cloud movement should be reported as the direction from which the clouds come and should be expressed in 10° as for winds (01-36).

All weather phenomena, such as lightning and fog, should be recorded by the symbols in Table 10 or Fig. 12. A numerical weather code is given in Table 8. The observer should be familiar with this table before selecting code numbers to describe weather. It is sometimes advisable to select the corresponding decade number in the first vertical column and follow this line horizontally until the most correct description of the weather is found.

4.1.6 Visibility

To estimate visibility for higher ranges the appearance of the land when coasting is a useful guide if fixes can be obtained. In the absence of other objects, the appearance of the horizon, as observed from different levels in the ship, may be used as a basis of estimation by experienced observers. At night, navigation lights can give a useful indication of visibility. The visibility code is given in Table 9.

When visibility is not uniform in all directions, it should be estimated or measured in the direction of least visibility and the direction of observation suitably recorded in the log. It is useful also to indicate the cause of low visibility by reference to the elements discussed in Section 4.1.5.

4.1.7. Some references on meteorological observation practices

Craig, R.A. and H.C. Willett, Compendium of Meteorology. American 1951 Meteorological Society.

Germany, Oberkommando der Kriegsmarine und das Reichsverkehrsministe- 1943 rium, Lehrbuch der Navigation I und II. Bremen, A. Geist, 515 and 393 p.

Halpine, C.G. and H.H. Taylor, A mariner's meteorology. London, Macmil- 1955 lan, 371 p.

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U.K., Meteorological Office, The meteorological glossary. London, HMSO, 1939 253 p.

U.K., Meteorological Office, The marine observer's handbook. London, 1950 HMSO, 122 p.

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......, Manual of cloud forms and codes for state of sky. Washington, 1949 Govt. Print. Off.

....., Instructions to marine meteorological observers. Washington, 1954 Govt. Print. Off.

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4.1.8. **Explanation of terms in Section** 4.1

Anemometer - Instrument for measuring wind speed.

Anemo-tachometer - Instrument for measuring wind speed. The actual speed can be read directly on the scale.

Aneroid (barometer) - A barometer in which the action of atmospheric pressure in bending a metallic surface is made to move a pointer

Climatology - The science which deals with climates and their effects.

Compass North - The direction of north, indicated by compass.

Deviation (navigational) - An unjustified and unnecessary departure from normal course or customary route.

Deviation (of compass) - The angle that a compass needle makes with the magnetic meridian, due to magnetic forces in the ship or cargo.

G.M.T. (Universal time) - Greenwich Mean Time. Time based on hour angle of point definition of mean time as measured at Greenwich.

Humidity - The condition of the atmosphere in respect of water vapor.

Hygrometer - An instrument for determining the humidity of the air (see Figures 9 - 10).

Magnetic North - The direction shown by the north-seeking pole of a compass needle

Port Meteorological Officer - Officer appointed by the meteorological services of corresponding countries to assist and supervise ships that report meteorological data.

Psychrometer - An alternative name for the dry and wetbulb hygrometer

Rain gauge - An instrument for measuring the amount of rainfall.

Synoptic - A brief or condensed statement presenting a combined or general view of something; e.g. a synoptic chart shows the weather conditions over a large area at a given instant of time.

True North - Direction to the true, or geographical North Pole.

W.M.O. - World Meteorological Organization.

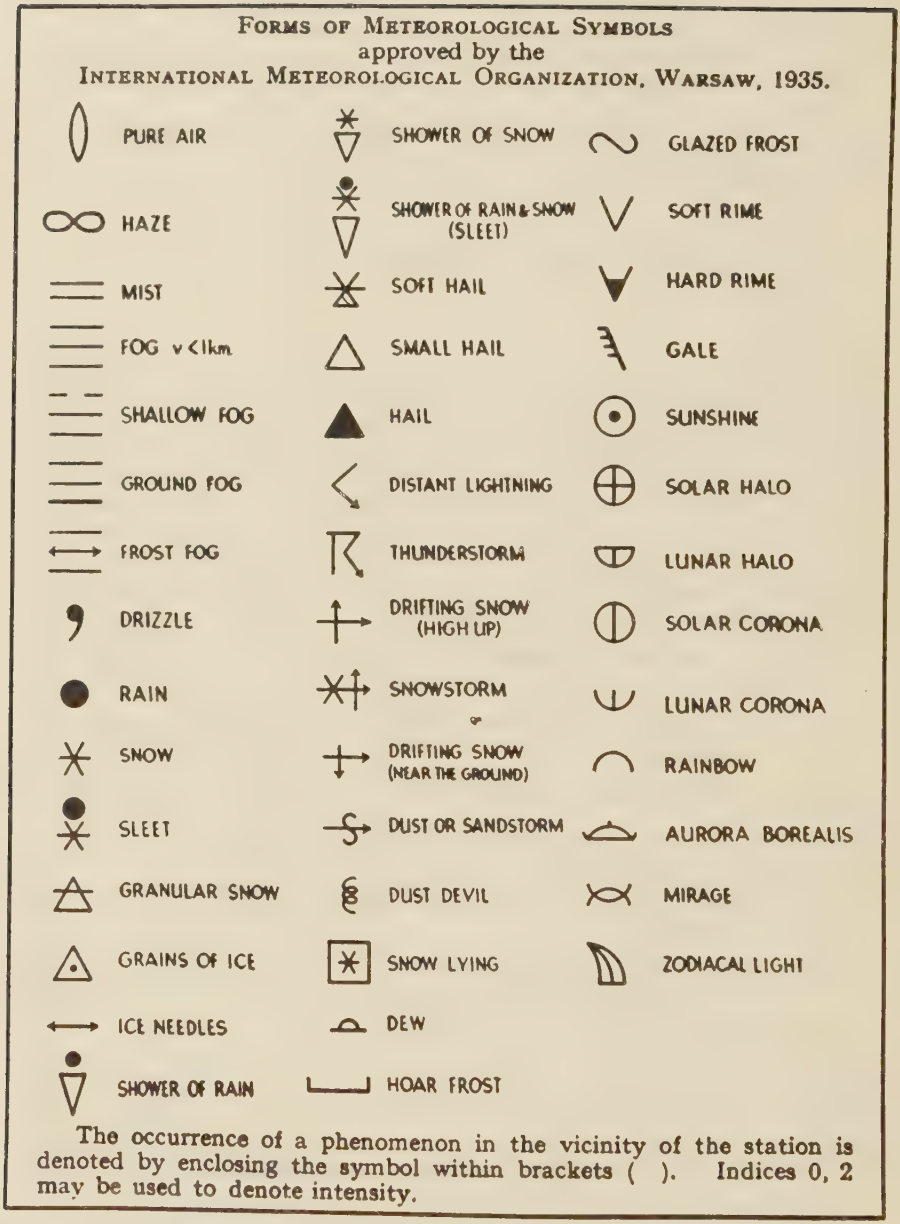


Figure 12. - Forms of meteorological symbols
(The Meteorological Glossary, H. M. S. O., London)

Table 1

Beaufort wind scale and its specification for sea and coastal use

Beaufort Scale Number	Descriptive Term	Coastal Criterion*	Sea Criterion
0	Calm	Calm	Sea like mirror.
1	Light airs	Fishing smack just has steerage-way.	Ripples with the appearance of scale are formed but without foam crests.
2	Light breeze	Winds fills the sails of smacks which then travel at about 1-2 knots.	Small wavelets, still short but more pronounced. Crests have a glassy appearance and do not break.
3	Gentle breeze	Smacks under top sails, and make up to 3 knots.	Large wavelets, crests begin to break. Foam of glassy appearance. Perhaps scattered with white horses.
4	Moderate breeze	Good working breeze. Smacks under all sail heel over considerably.	Small waves becoming larger; fairly frequent white horses.
5	Fresh breeze	Smacks shorten sail.	Moderate waves, taking a more pronounced long form; many white horses are formed. Chances of some spray.
6	Strong breeze	Smacks have double reef in main sail. Care required when fishing	Large waves begin to form; the white foam crests are more extensive everywhere. Probably more spray.
7	Near gale	Smacks remain in harbour and those at sea lie to.	Sea heaps up and white foam from breaking waves begins to be blown in streaks along the direction of the wind.
8	Gale	All smacks make for harbour, if near.	Moderately big waves of greater length; edges of crests begin to break into spindrift. The foam is blown in well-marked streaks along the direction of the wind.

Table 1 (Cont'd)

Beaufort Scale Number	Descriptive Term	Coastal Criterion*	Sea Criterion
9	Stong gale		High waves. Dense streaks of foam along the direction of the wind. Sea begins to "roll". Spray may affect visibility
10	Storm		Very big waves with long overhanging crests. The resulting foam, in great patches, is blown in dense white streaks along the direction of the wind. On the whole the surface of the sea assumes a white appearance. The rolling of the sea becomes heavy and shock-like. Visibility affected.
11	Violent storm		The conditions become progressively worse.
12	Hurricane		

* The fishing smack in this table may be taken as representing a trawler of average type and trim. Allowance must be made for larger or smaller boats and for special circumstances.

Table 2

Maritime conversion scale for wind speed

Beaufort Number	Meters per Second		Knots	
	mean	limits	mean	limits
0	0	< 0.6	0	1
1	1.5	0.7– 2.3	3	1– 4
2	3.4	2.4– 4.4	7	5– 8
3	5.6	4.5– 6.6	11	9–12
4	7.8	6.7– 8.9	15	13–16
5	10.2	9.0–11.3	19	17–21
6	12.6	11.4–13.8	24	22–26
7	15.1	13.9–16.4	29	27–31
8	17.7	16.5–19.0	34	32–36
9	20.4	19.1–21.8	39	37–42
10	23.3	21.9–24.8	45	43–48
11	26.5	24.9–28.2	52	49–55
12	–	>28.2	–	>55

Table 3

Conversion of barometric pressure from millimeters to millibars

mm.	0	1	2	3	4	5	6	7	8	9	Decimals	
	mb	mb	mb	mb	mb	mb	mb	mb	mb	mb	Milli-meter	Milli-bar
680	906.6	907.9	909.2	910.6	911.9	913.2	914.6	915.9	917.2	918.6		
690	919.9	921.2	922.6	923.2	925.2	926.6	927.9	929.2	930.6	931.9		
											1	1
700	933.2	934.6	935.9	937.9	938.6	939.9	941.2	942.6	943.9	945.2		
											2	3
710	946.6	947.9	949.2	950.6	951.9	953.2	954.6	955.9	957.2	958.6	3	4
720	959.9	961.2	962.6	963.9	965.2	966.6	967.9	969.2	970.6	971.9	4	5
730	973.2	974.6	975.9	977.2	978.6	979.9	981.2	982.6	983.9	985.2		
											5	7
740	986.6	987.9	989.2	990.6	991.9	993.2	994.6	995.9	997.2	998.6		
											6	8
750	999.9	1001.2	1002.6	1003.9	1005.2	1006.6	1007.9	1009.2	1010.9	1011.9	7	9
											8	11
760	1013.2	1014.6	1015.9	1017.2	1018.6	1019.9	1021.2	1022.6	1023.9	1025.2		
770	1026.6	1027.9	1029.2	1030.6	1031.9	1033.2	1034.6	1035.9	1037.2	1038.6	9	12
780	1039.9	1041.2	1042.6	1043.9	1045.2	1046.6	1047.9	1049.2	1050.6	1051.9		
790	1053.2	1054.6	1055.9	1057.2	1058.6	1059.9	1061.2	1062.6	1063.9	1065.2		

Table 4

Temperature conversion - Centigrade to Fahrenheit

°C.	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
−2	28.40	28.22	28.04	27.86	27.68	27.50	27.32	27.14	26.96	26.78
−1	30.20	30.02	29.84	29.66	29.48	29.30	29.12	28.94	28.76	28.58
0	32.00	31.82	31.64	31.46	31.28	31.10	30.92	30.74	30.56	30.38
0	32.00	32.18	32.36	32.54	32.72	32.90	33.08	33.26	33.44	33.62
1	33.80	33.98	34.16	34.34	34.52	34.70	34.88	35.06	35.24	35.42
2	35.60	35.78	35.96	36.14	36.32	36.50	36.68	36.86	37.04	37.22
3	37.40	37.58	37.76	37.94	38.12	38.30	38.48	38.66	38.84	39.02
4	39.20	39.38	39.56	39.74	39.92	40.10	40.28	40.46	40.64	40.82
5	41.00	41.18	41.36	41.54	41.72	41.90	42.08	42.26	42.44	42.62
6	42.80	42.98	43.16	43.34	43.52	43.70	43.88	44.06	44.24	44.42
7	44.60	44.78	44.96	45.14	45.32	45.50	45.68	45.86	46.04	46.22
8	46.40	46.58	46.76	46.94	47.12	47.30	47.48	47.66	47.84	48.02
9	48.20	48.38	48.56	48.74	48.92	49.10	49.28	49.46	49.64	49.82
10	50.00	50.18	50.36	50.54	50.72	50.90	51.08	51.26	51.44	51.62
11	51.80	51.98	52.16	52.34	52.52	52.70	52.88	53.06	53.24	53.42
12	53.60	53.78	53.96	54.14	54.32	54.50	54.68	54.86	55.04	55.22
13	55.40	55.58	55.76	55.94	56.12	56.30	56.48	56.66	56.84	57.02
14	57.20	57.38	57.56	57.74	57.92	58.10	58.28	58.46	58.64	58.82
15	59.00	59.18	59.36	59.54	59.72	59.90	60.08	60.26	60.44	60.62
16	60.80	60.98	61.16	61.34	61.52	61.70	61.88	62.06	62.24	62.42
17	62.60	62.78	62.96	63.14	63.32	63.50	63.68	63.86	64.04	64.22
18	64.40	64.58	64.76	64.94	65.12	65.30	65.48	65.66	65.84	66.02
19	66.20	66.38	66.56	66.74	66.92	67.10	67.28	67.46	67.64	67.82
20	68.00	68.18	68.36	68.54	68.72	68.90	69.08	69.26	69.44	69.62
21	69.80	69.98	70.16	70.34	70.52	70.70	70.88	71.06	71.24	71.42
22	71.60	71.78	71.96	72.14	72.32	72.50	72.68	72.86	73.04	73.22
23	73.40	73.58	73.76	73.94	74.12	74.30	74.48	74.66	74.84	75.02
24	75.20	75.38	75.56	75.74	75.92	76.10	76.28	76.46	76.64	76.82
25	77.00	77.18	77.36	77.54	77.72	77.90	78.08	78.26	78.44	78.62
26	78.80	78.98	79.16	79.34	79.52	79.70	79.88	80.06	80.24	80.42
27	80.60	80.78	80.96	81.14	81.32	81.50	81.68	81.86	82.04	82.22
28	82.40	82.58	82.76	82.94	83.12	83.30	83.48	83.66	83.84	84.02
29	84.20	84.38	84.56	84.74	84.92	85.10	85.28	85.46	85.64	85.82
30	86.00	86.18	86.36	86.54	86.72	86.90	87.08	87.26	87.44	87.62
31	87.80	87.98	88.16	88.34	88.52	88.70	88.88	89.06	89.24	89.42
32	89.60	89.78	89.96	90.14	90.32	90.50	90.68	90.86	91.04	91.22
33	91.40	91.58	91.76	91.94	92.12	92.30	92.48	92.66	92.84	93.02
34	93.20	93.38	93.56	93.74	93.92	94.10	94.28	94.46	94.64	94.82
35	95.00	95.18	95.36	95.54	95.72	95.90	96.08	96.26	96.44	96.62
36	96.80	96.98	97.16	97.34	97.52	97.70	97.88	98.06	98.24	98.42
37	98.60	98.78	98.96	99.14	99.32	99.50	99.68	99.86	100.04	100.22
38	100.40	100.58	100.76	100.94	101.12	101.30	101.48	101.66	101.84	102.02
39	102.20	102.38	102.56	102.74	102.92	103.10	103.28	103.46	103.64	103.82
40	104.00	104.18	104.36	104.54	104.72	104.90	105.08	105.26	105.44	105.62
41	105.80	105.98	106.16	106.34	106.52	106.70	106.88	107.06	107.24	107.42
42	107.60	107.78	107.96	108.14	108.32	108.50	108.68	108.86	109.04	109.22
43	109.40	109.58	109.76	109.94	110.12	110.30	110.48	110.66	110.84	111.02
44	111.20	111.38	111.56	111.74	111.92	112.10	112.28	112.46	112.64	112.82
45	113.00	113.18	113.36	113.54	113.72	113.90	114.08	114.26	114.44	114.62
46	114.80	114.98	115.16	115.34	115.52	115.70	115.88	116.06	116.24	116.42
47	116.60	116.78	116.96	117.14	117.32	117.50	117.68	117.86	118.04	118.22
48	118.40	118.58	118.76	118.94	119.12	119.30	119.48	119.66	119.84	120.02
49	120.20	120.38	120.56	120.74	120.92	121.10	121.28	121.46	121.64	121.82

Table 5

Beaufort weather notations

b – blue sky, weather with clear or hazy atmosphere.

c – cloudy, i.e. either detached clouds or a cloud layer with openings.

d – drizzle

e – wet air without rain falling, a copious deposit of water on trees, buildings or riggings.

f – fog.

fg – ground fog.

fs – shallow fog.

fe – wet fog.

g – gale

h – hail

ks – drifting snow.

kz – duststorm or sandstorm

l – distant lightning.

m – mist; range of visibility 1100 - 2200 yards.

o – overcast i.e. the whole sky covered with a uniform layer of thick or heavy clouds.

p – showers.

q – squalls.

r – rain.

vs – sleet, i.e. rain and snow together.

s – snow.

t – thunder.

tl – thunderstorm.

u – ugly, threatening sky.

v – unusual visibility of distant objects.

w – dew.

x – hoar-frost.

y – dry air (less than 60% relative humidity).

z – haze; range of visibility 1100 - 2200 yards.

R	– heavy rain	RR	– continuous heavy rain
r	– (moderate) rain	rr	– continuous (moderate) rain
ro	– slight rain	iro	– intermittent slight rain
pr	– rain showers	pS	– heavy snow showers

Table 6

Code for cloud types

0.	Stratus or fractostratus.
1.	Cirrus.
2.	Cirro-stratus.
3.	Cirrocumulus.
4.	Altostratus.
5.	Altocumulus.
6.	Stratuscumulus.
7.	Nimbostratus.
8.	Cumulus or fractocumulus.
9.	Cumulonimbus.

Table 7

Code for reporting cloudiness

Scale Number	*Amount of cloud*
0.	None.
1.	1 oktas or 1/8 of sky covered.
2.	2 oktas or 2/8 of sky covered.
3.	3 oktas or 3/8 of sky covered.
4.	4 oktas or 4/8 of sky covered.
5.	5 oktas or 5/8 of sky covered.
6.	6 oktas or 6/8 of sky covered.
7.	7 oktas or 7/8 of sky covered.
8.	8 oktas or sky completely covered.
9.	Sky obscured (e.g. by fog) or amount of cloud not recordable owing to darkness.

NUMERICAL WEATHER CODES—PRESENT WEATHER

00 Cloud development NOT observed or NOT observable during past hour	**01** Clouds generally dissolving or becoming less developed during past hour	**02** State of sky on the whole unchanged during past hour	**03** Clouds generally forming or developing during past hour	**04** Visibility reduced by smoke	**05** Haze	**06** Widespread dust in suspension in the air NOT raised by wind at time of observation	**07** Dust or sand raised by wind at time of observation	**08** Well developed dust devil(s) within past hour	**09** Duststorm or sandstorm within sight of or at station during past hour
10 Light fog	**11** Patches of shallow fog at station NOT deeper than 6 feet on land	**12** More or less continuous shallow fog at station NOT deeper than 6 feet on land	**13** Lightning visible no thunder heard	**14** Precipitation within sight but NOT reaching the ground	**15** Precipitation within sight reaching the ground but distant from station	**16** Precipitation within sight reaching the ground near to but NOT at station	**17** Thunder heard but no precipitation at the station	**18** Squall(s) within sight during past hour	**19** Funnel cloud(s) within sight during past hour
20 Drizzle (NOT freezing and NOT falling as showers) during past hour, but NOT at time of ob	**21** Rain (NOT freezing and NOT falling as showers) during past hour but NOT at time of ob	**22** Snow (NOT falling as showers) during past hour but NOT at time of observation	**23** Rain and snow (NOT falling as showers) during past hour but NOT at time of observation	**24** Freezing drizzle or freezing rain (NOT falling as showers) during past hour but NOT at time of observation	**25** Showers of rain during past hour but NOT at time of observation	**26** Showers of snow or of rain and snow during past hour but NOT at time of observation	**27** Showers of hail or of hail and rain during past hour but NOT at time of observation	**28** Fog during past hour but NOT at time of observation	**29** Thunderstorm (with or without precipitation) during past hour but NOT at time of observation
30 Slight or moderate duststorm or sandstorm has decreased during past hour	**31** Slight or moderate duststorm or sandstorm no appreciable change during past hour	**32** Slight or moderate duststorm or sandstorm has increased during past hour	**33** Severe duststorm or sandstorm has decreased during past hour	**34** Severe duststorm or sandstorm no appreciable change during past hour	**35** Severe duststorm or sandstorm has increased during past hour	**36** Slight or moderate drifting snow generally low	**37** Heavy drifting snow generally low	**38** Slight or moderate drifting snow generally high	**39** Heavy drifting snow generally high
40 Fog at distance at time of observation but NOT at station during past hour	**41** Fog in patches	**42** Fog, sky discernible has become thinner during past hour	**43** Fog sky NOT discernible has become thinner during past hour	**44** Fog, sky discernible no appreciable change during past hour	**45** Fog sky NOT discernible no appreciable change during past hour	**46** Fog sky discernible has begun or become thicker during past hour	**47** Fog sky NOT discernible has begun or become thicker during past hour	**48** Fog depositing rime sky discernible	**49** Fog depositing rime sky not discernible
50 Intermittent drizzle (NOT freezing) slight at time of observation	**51** Continuous drizzle (NOT freezing) slight at time of observation	**52** Intermittent drizzle (NOT freezing) moderate at time of ob	**53** Continuous drizzle (NOT freezing) moderate at time of ob	**54** Intermittent drizzle (NOT freezing), thick at time of observation	**55** Continuous drizzle (NOT freezing) thick at time of observation	**56** Slight freezing drizzle	**57** Moderate or thick freezing drizzle	**58** Drizzle and rain slight	**59** Drizzle and rain moderate or heavy
60 Intermittent rain (NOT freezing), slight at time of observation	**61** Continuous rain (NOT freezing) slight at time of observation	**62** Intermittent rain (NOT freezing) moderate at time of ob	**63** Continuous rain (NOT freezing) moderate at time of observation	**64** Intermittent rain (NOT freezing), heavy at time of observation	**65** Continuous rain (NOT freezing) heavy at time of observation	**66** Slight freezing rain	**67** Moderate or heavy freezing rain	**68** Rain or drizzle and snow slight	**69** Rain or drizzle and snow moderate or heavy
70 Intermittent fall of snowflakes, slight at time of observation	**71** Continuous fall of snowflakes, slight at time of observation	**72** Intermittent fall of snowflakes moderate at time of observation	**73** Continuous fall of snowflakes moderate at time of observation	**74** Intermittent fall of snowflakes heavy at time of observation	**75** Continuous fall of snowflakes heavy at time of observation	**76** Ice needles (with or without fog)	**77** Granular snow (with or without fog)	**78** Isolated starlike snow crystals (with or without fog)	**79** Ice pellets (sleet U S definition)
80 Slight rain shower(s)	**81** Moderate or heavy rain shower(s)	**82** Violent rain shower(s)	**83** Slight shower(s) of rain and snow mixed	**84** Moderate or heavy shower(s) of rain and snow mixed	**85** Slight snow shower(s)	**86** Moderate or heavy snow shower(s)	**87** Slight shower(s) of soft or small hail with or without rain or rain and snow mixed	**88** Moderate or heavy shower(s) of soft or small hail with or with out rain or rain and snow mixed	**89** Slight shower(s) of hail with or without rain or rain and snow mixed not associated with thunder
90 Moderate or heavy shower(s) of hail with or without rain or rain and snow mixed not associated with thunder	**91** Slight rain at time of ob thunderstorm during past hour but NOT at time of observation.	**92** Moderate or heavy rain at time of ob thunderstorm during past hour, but NOT at time of observation	**93** Slight snow or rain and snow mixed or hail at time of observation thunderstorm during past hour, but not at time of observations	**94** Mod or heavy snow, or rain and snow mixed or hail at time of ob thunderstorm during past hour, but NOT at time of observation	**95** Slight or mod thunderstorm without hail but with rain and or snow at time of observation	**96** Slight or moderate thunderstorm, with hail at time of observation	**97** Heavy thunderstorm without hail but with rain and or snow at time of observation	**98** Thunderstorm combined with duststorm or sandstorm at time of observation	**99** Heavy thunderstorm with hail at time of observation

Table 9

Visibility code

Code	Objects not visible at –	Description
0	50 yards	Dense fog.
1	200 yards	Thick fog.
2	400 yards	Fog.
3	1,000 yards	Moderate fog.
4	1 nautical mile	Thin fog or mist.
5	2 nautical miles	Visibility poor.
6	5 nautical miles	Visibility moderate.
7	10 nautical miles	Visibility good.
8	30 nautical miles	Visibility very good.
9	Over 30 miles	Visibility excellent.

Table 10

MET CODE

For Use of Reporting Ships in Sparse Areas

GROUP No 1
Y Q L_a L_a L_a

Y = Day of the Week
1 = Sunday
2 = Monday
3 = Tuesday
4 = Wednesday
5 = Thursday
6 = Friday
7 = Saturday

Q = Longitude and Hemisphere Indicator

NORTHERN HEMISPHERE
0 = 0_o– 90°WEST
1 = 90_o–180°WEST
2 = 90_o–180° EAST
3 = 0_o– 90° EAST

SOUTHERN HEMISPHERE
5 = 0°– 90°WEST
6 = 90°–180°WEST
7 = 90°–180° EAST
8 = 0°– 90° EAST

$L_aL_aL_a$ = Latitude in degrees and tenths.
Example: 31°28' South = 31.5
$L_aL_aL_a$ = 315

GROUP No. 2
$L_oL_oL_o$ G G

$L_oL_oL_o$ = Longitude in degrees and tenths.
Examples: $04_o05'$ East = 04.1
$L_oL_oL_o$ = 041

102°10' EAST = = 102.2 $L_oL_oL_o$ = = 022
(N.B. The "1" is omitted).

GROUP No. 3
N d d f f

N = Cloud coverage
0 =
2 =
4 = (WMO-Specifications Code 60)
6 =
8 =
9 =

dd = True Direction of the Wind on the Sea Surface to the nearest 10°
dd = Pts. of Compass Degrees

00	Calm	
02	NNE	20°
	NE	
04		40°
06		60°
	ENE	
08		80°
	E	
10		100°
12	ESE	120°
	SE	
14		140°
16	SSE	160°
18	S	180°
20	SSW	200°
22	SW	220°
24		240°
	WSW	
26		260°
28		280°
	WNW	
30		300°
32	NW	320°
34	NNW	340°
36	N	360°

GROUP No. 4
V V w w W

VV = Visibility
90 =
91 =
92 =
93 =
94 = (WMO-Specifications Code 84)
95 =
96 =
97 =
98 =
99 =

ww = Present Weather
01 =
02 =
03 =
05 =
10 =
16 =
18 =
41 = (WMO-Specifications Code 92)
45 =
52 =
57 =
62 =
67 =
72 =
81 =
86 =
90 =
95 =
Chose the largest figure applicable.
41–95: If no figure is suitable, put «X» in units position.
For ex. 6x = rain when neither 62 nor 67 apply.

GROUP No. 5
P P X T T

PP = Last two figures of the barometric pressure in millibars.
Examples:

	mb	PP
30.32" =	1026.8	27
749 mm =	998.6	99

X = x (Indicator to show type of reporting ship)

TT = Outside air temperature in degrees F or C
Examples:

	TT
57°F =	57
19°C =	19
6°C =	06
–2°C =	52

Note$_o$ 50 is added to temperatures BELOW 0°C

INSTRUCTIONS

1. In the interest of trans-ocean flying as well as safety of life at sea, your ship is earnestly requested to transmit radio weather reports when off the regular shipping routes.

Table 10 (Cont'd)

GROUP No. 2 $L_oL_oL_o$ G G	GROUP No. 3 N d d f f	GROUP No. 4 V V w w W	GROUP No. 5 P P X T T
GG = G.M.T. of the Observation to the nearest hour: 00 = 0000 GMT 06 = 0600 » 12 = 1200 » 18 = 1800 » N.B. Please take the observations as near to these times as possible.	ff = Wind Speed over sea surface in KNOTS. KNOTS – ff EQUIVALENT – BEAUFORT – FORCE 00 = Calm 02 = 1 05 = 2 09 = 3 13 = 4 18 = 5 24 = 6 30 = 7 37 = 8 44 = 9 52 = 10 60 = 11 68 = 12	W = Past Weather (during the preceeding 6 hours). 0 = 1 = 2 = 3 = 4 = (WMO-Specifications Code 90) 5 = 6 = 7 = 8 = 9 =	2. Address reports to: ..... followed by the name of the nearest coastal radio station shown on the map. There is NO CHARGE to ships for Radio WEATHER messages to these stations. 3. The cooperation of all ships will enable Weather Services to provide better and more reliable shipping and aviation forecasts. 4. Whenever possible have your barometer checked and remember to apply the appropriate correction.

Form 7

Met. Data Sheet (and BT Data)

a. Anemometer Height

b. Thermometer Height

c. Vessel

d. Month

e. Year

f. Cruise

1	2	3	4	5		6		7	8	9		10	11	12		13		14	15	16	17	18
Time	Date	Latitude	Longitude	Wind		Air Temp. °C		Barometer - mb	Weather	Clouds		Visibility	Surf. Temp. °C	Sea		Swell		BT No.	Slide No.	Speed Knots		Observer's Initials
				Direction True	Speed	Dry Bulb	Wet Bulb			Formation	Amount			Direction	Amount	Direction	Amount					
				5.1	5.2	6.1	6.2			9.1	9.2			12.1	12.2	13.1	13.2					

NOTES ON FORM 7: MET. DATA SHEET (AND BT DATA)

The method of observation and codes to be used for filling this log are given in Section 4.1 Meteorological observations should be made at: a) every station; b) for every BT lowering; c) the standard hour of observation while underway, when the ship is reporting to meteorological offices.
Notes:-

a and b – Give anemometer and thermometer heights above sea level.

1 – Give Greenwich Mean Time

5 2 – Give wind speed in knots if measured with anemeter, otherwise give the force in the Beaufort scale.

7 – Give uncorrected barometer reading (in 2 digits) neglecting 900 and 1000.

4.2 THE SEA - OCEANOGRAPHICAL OBSERVATIONS

It is unnecessary to repeat here the remarks made earlier concerning the place of this kind of work in an overall programme of research in fisheries biology, but it is necessary to make some general observations concerning the care and handling of oceanographic instruments.

Practice is necessary for the proper handling and care of all instruments. It should always be borne in mind that since it is extremely difficult and often impossible to repair broken instruments on small vessels, the failure of an instrument may mean the failure of the entire programme of work and that a voyage may have been made in vain. Therefore, in addition to skill and care in handling, the instruments must be properly secured to the ship even during calm weather. An unexpected wave, when the sea is smooth, such as generated by a passing ship, has often caused great damage in a ship's laboratory where no precautions had been taken. If possible, spare instruments should be carried.

Instruments should always be properly dried and cleaned immediately after use. Metal instruments should be rinsed with fresh water if possible. Greasing and degreasing is a regular job on certain types of oceanographical equipment. Silicon grease should be given preference.

4.2.1 Observations of sea surface

Adequate observations of sea surface can be made simply without instruments, provided consistency and accuracy of description are maintained. This can be effected by careful use of the appropriate meteorological and sea-surface codes.

SEA AND SWELL

Wind waves and swell should be observed and recorded separately. They are usually superimposed and a certain amount of practice is necessary to distinguish between them. The following notes will be found of assistance.

Sea (wind waves) - waves caused by wind in the immediate neighbourhood at the time of observation. The direction of the waves is usually the same as that of the wind, except when the wind changes direction quickly. The wind-wave period is usually smaller than that of the swell; also wind waves are steeper.

Swell - a system of waves created by winds at a distance from the point of observation. The period is long and the wave round.

The wave characteristics which should be used for reporting are:-

Length – the horizontal distance between successive crests or troughs. (equal to the wave period multiplied by the wave speed).

Period – the time between the passage of two successive wave crests past a fixed point (equal to the wave length divided by the wave speed).

Speed – the distance travelled by a wave in unit time (equal to the wave length divided by the wave period).

Height – the vertical distance between trough and crest.

The period, direction and height can easily be observed. *Period* can be determined by noting some small object or patch of foam on the surface. and with a stop-watch, timing the interval between its appearance on the crest of one wave and its appearance on the crest of the next wave. Many observations should be made of the same object and the period recorded as the mean calculated by dividing the total time, measured with the stop-watch, by the number of appearances of the object on the wave crests. *The direction* from which the waves come can be ascertained by adding or subtracting 90^{o} to or from the compass bearing of the crests. To estimate *the height* of small waves the observer should be close to the sea surface and preferably amidships. To estimate the height of high waves the observer should climb up and down the mast and record the height of his eye from sea level when he sees the crest of the wave relative to the horizon. The average height of the larger well-formed waves should be recorded.

When making simple wave observations from coastal stations care must be taken to choose a site from which shallowness and/or reflection does not give false impressions of the waves. For such observations special wave recorders are available but need experts to instal them and special instruction for interpretation of their records. A graduated line at the end of a

pier or an anchored floating buoy will give reasonably accurate visual measures of both wave height and period. The codes for recording sea and swell are set out in Tables 11-12. The following phenomena should also be observed and reported:

Breakers – the collapse of a whole wave when it runs into very shallow water (about twice the wave length).

Surf – the broken water between the shoreline and the outermost line of the breakers.

Breaking sea – the partial collapse of the crest of a wave, caused by:

a) action of the wind;

b) steepening of the wave when it meets a contrary current or tidal stream;

c) steepening of the wave when it runs into shoal water not shallow enough to cause a breaker.

ICE

Sea ice can be recorded according to the code given in Tables 13-14. A revised ice code and classification with illustrations is being prepared by W.M.O. The nature, amount and size of the ice should be recorded, using the special observation codes.

COLOUR

By "colour" of the sea is meant the colour of the sea water and not that of light reflected from the surface, nor the reflection of the clouds and the sky. The colour depends on the scattering of light by water molecules and by suspended matter in the water. The colour of clear sea water is nearest to blue. Nature and size of suspended matter then cause variation from this. The greenish colour in coastal waters, for example, depends largely on the amount of so-called "yellow substance" present. Colour changes indicate different water masses and boundaries between them.

Colour is usually estimated according to the Forel (or Osvald) colour scales, or described exactly with the simple colour adjectives. The Forel colour scale is given in Table 15. The chemical methods used for measuring colour of fresh water (e.g. platinum-cobalt or methylorange standards) cannot be used in sea water. Several special kinds of optical apparatus can be used, but these require that the determination should be made immediately at the station where water samples are taken. References for these methods are given in Section 4.2.6.

Visual observation (underway or at the station) are made on the shadow side of the ship, in order to minimise the effect of sun glitter. The estima-

tion of the colour (in the Forel scale) at stations should be made against the white (Secchi) disc suspended in the water at a depth of 1 meter (see the determination of transparency with the Secchi disc, 4.2.5). All discolourations of the water (e.g. phosphorescence) should be recorded, as should observations of drifting detritus and objects on the surface.

SEA SURFACE TEMPERATURE

It is advisable to record sea surface temperature at frequent intervals, when the ship is under way, because rapid changes in temperature distances are generally indicative of current divergences and convergences whose presence is always of considerable significance. The temperature of the sea surface can easily be measured by the "bucket" method while under way. In large ships temperature of condensor intake water is recorded continuously, but this is of course somewhat deeper.

For temperature determination the sample of water should be taken with a special bucket on the leeward side far from all outlets. The bucket should not have been in direct sunshine prior to use. It should be towed astern for at least 3 minutes. If the bucket is equipped with a special fixed thermometer, this should be read immediately the sample arrives on board. When a loose thermometer is used, it is held by the upper end and moved around in the water for a minute or two. The thermometer should have a small heat capacity and it should not be lifted out from the water for reading. The reading should be made with an accurancy of $\pm$ 0.2°F. or $\pm$ 0.1°C. A surface "bucket" is illustrated in the Figure 13.

TIDES

Continuous recording of tides is made by special tide gauges. Special observations are made at coastal stations by reading graduated water level gauges on piers. The reference level of these gauges should be selected according to the standard practice in the country (e.g. mean low low water, lowest low water, mean sea level etc.). Information on tides is usually available in tide tables issued for certain specific areas or ports, and usually computed for a year ahead. The observers should make themselves familar, from special publications, with the nature of the tides (i.e. diurnal, semi-diurnal, range, etc.) in the area of interest.

4.2.2 Hydrographical observations

Hydrographical observations are made and samples are taken at stations whose position is usually planned beforehand (see Section 1).

It is of utmost importance that everything should be in readiness for the work of a station; all clearing up after each station should be done without

delay, and log sheets should be prepared, instruments checked and cleared, and sampling bottles got ready, whilst the ship is under way from one station to another.

HYDROGRAPHIC EQUIPMENT

Mounted hydrographic winches of different types are part of the equipment and are not discussed here. Portable hand winches used on small boats (Fig. 14) must be securely fixed. These winches must have two brakes: one to regulate the lowering speed and a second to arrest the cable effectively. Cables, of which the best kinds are rustless, must be thin and flexible, and must be handled carefully to avoid twisting, and should be checked often at wearing and weak spots. The weight at the end of the cable should be sufficient to allow different lowering speeds and to prevent sliding on the meter wheel. The meter wheel should be easily readable both by the winch and instrument operators (Fig. 15).

Many different types of water samplers (bottles) are in use (Figs. 16-18). These can be classified as single and series samplers. The most common single type is the Pettersson bottle (Fig. 16), which should not be used at greater depths than 200 metres. Series samplers either reverse themselves when closed by a "messenger", or are equipped with a reversible thermometer frame. A messenger is hung below each bottle. Reversing of the bottles is initiated by sending down a messenger from the ship; this reverses the first bottle and releases its messenger which causes the second bottle to reverse, and so on. This "chain reaction" can be detected by feeling the vibrations carried through the line so that if a bottle should not reverse and will not release its messenger, the observer will know that the action is incomplete. Bottles sometimes reverse and close prematurely (a) if the end weight is too light, (b) if the cast is lowered too rapidly, and (c) in heavy seas. Care should be taken that the bottles are fastened to the wire, so that no sliding occurs, and that they remain open when they hit the surface on lowering and until the messenger strikes them.

TEMPERATURE

Water samplers are fitted with frames usually to hold two reversible thermometers (Fig. 19). One thermometer is protected against pressure and the other is unprotected. The unprotected thermometer serves for checking and/or recording the depth at which the sample has been taken. Simpler and cheaper samplers, which are often suitable for fisheries work, have usually ony one reversible thermometer (pressure protected).

The cast is made from a work platform or board on the weather side of the ship, and the depth of the water must be checked from the bridge. If possible, samples should be taken at standard depths of observation: 0, 10, 20, 30, 50, 75, 100, 150, 200, (250), 300, 400, 500, 600, (700), 800, 1000, 1200,

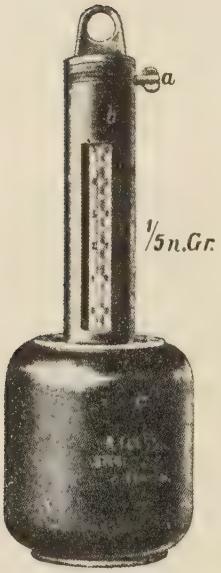


Figure 13. - Surface bucket with thermometer

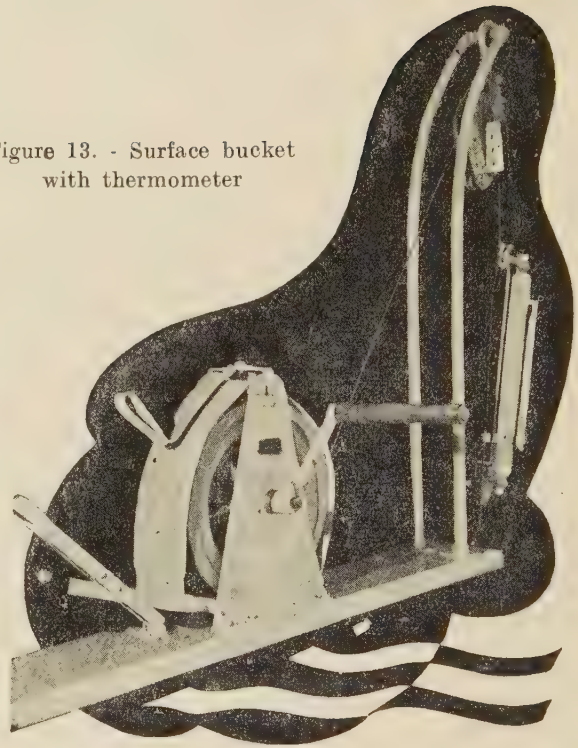


Figure 14. - Hand winch (Courtesy Bergen Nautik, Bergen, Norway)

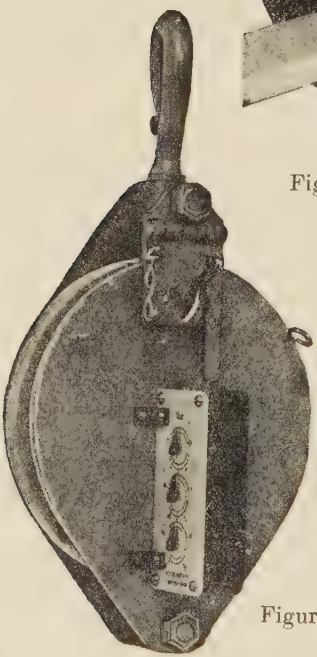


Figure 15. - Meter wheel (Courtesy Bergen Nautik, Bergen, Norway)

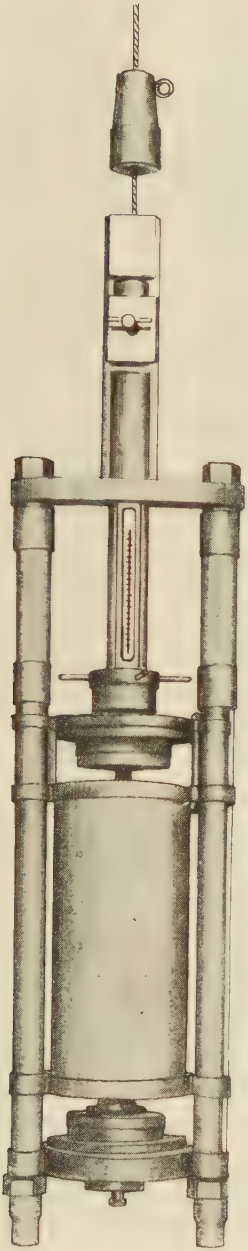


Figure 16 - Pettersson-Nansen bottle

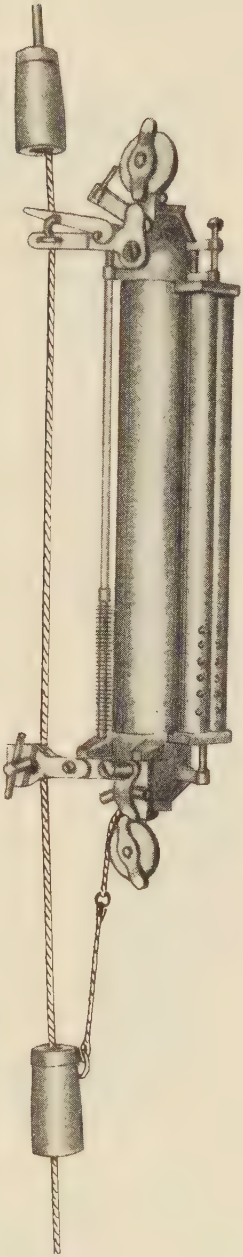


Figure 17 - Nansen reversing water bottle

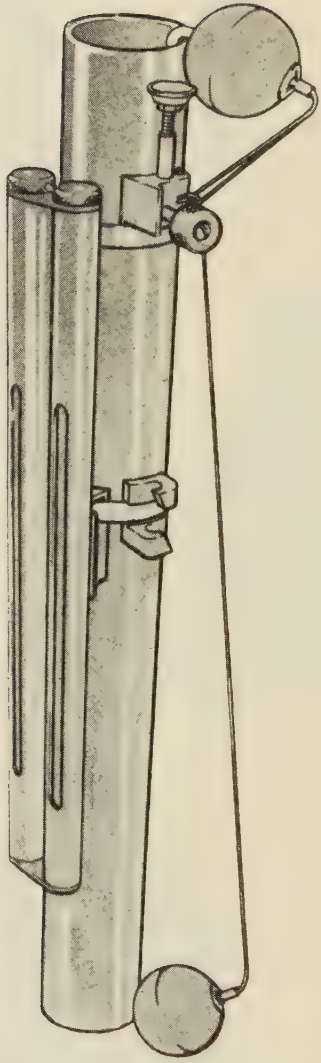


Figure 18 - Frautschy bottle (Courtesy Hytech Corp., Inglewood, Calif., USA)

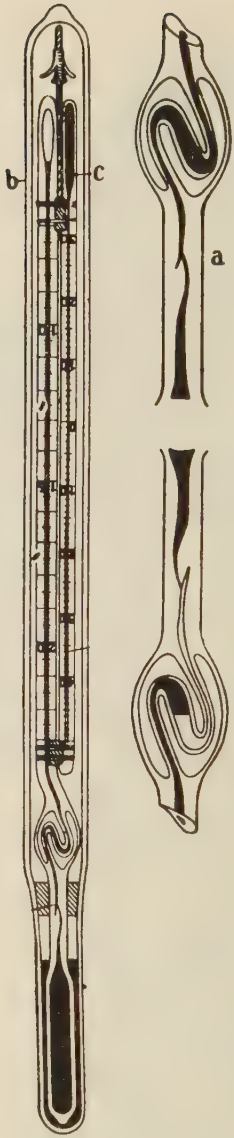
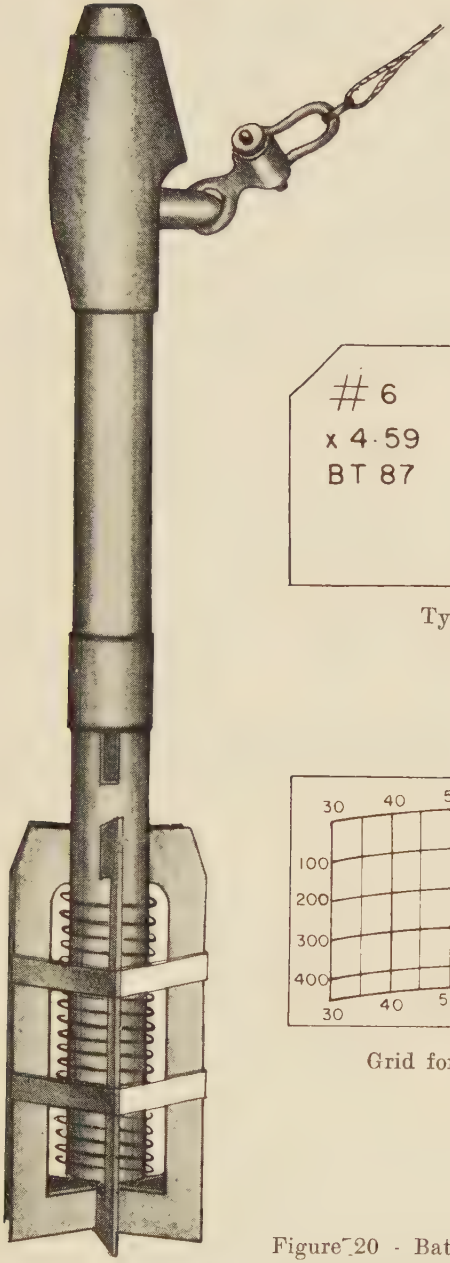
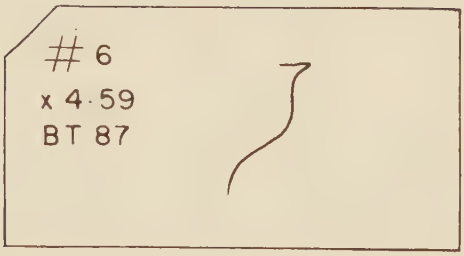
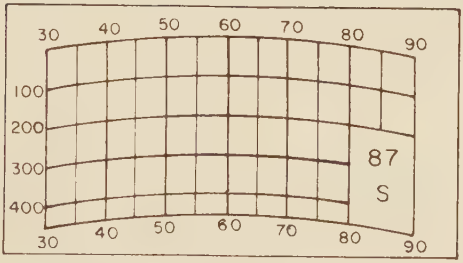


Figure 19 - Reversing thermometer (pressure protected)





Typical recording



Grid for reading recording

Figure 20 - Bathythermograph

1500, 2000, 3000, 4000 metres. At least five minutes should pass after a cast has been lowered into position before the messenger is sent to close the bottles, to allow each thermometer to register the temperature of the water layer in which it lies. Before the messenger is dropped the angle of the wire with the sea surface is measured, so that the actual depth of the samples can be calculated. When hauling in, in rough weather care must be taken that the bottles do not hit against the ship. When the samplers are hauled aboard and loosened from the wire, care must be taken not to turn them on their side but place them vertically into the rack as they come from the water.

The thermometers should be read with a thermometer reader, the main one to an accuracy of $\pm$ 0.01°C and the auxiliary to $\pm$ 0.1°C. The auxiliary thermometer shows the temperature of the thermometer at the time of reading and which serves for correction of the actual temperature.

Bathythermographs (Fig. 20) are used for continuous recording of temperature and depth in upper water layers. BT can be lowered either at the station or underway. The record is made by the instrument on smoked slides, one of which is used for each lowering. In operation the BT is lowered into the surface water and held there for about 30 seconds to allow the instrument to adjust to the temperature of the sea surface.

After that more wire is paid out. The length of wire run out during underway measurements depends on the ship's speed and the condition of the control gear. Several trial runs should be made to determine the length of wire necessary to reach the depths sought. The surface temperature should always be taken with the bucket thermometer when the BT is lowered and recorded on the BT log. The BT should never be kept in temperature exceeding 105°F (ca 40°C).

The slides are numbered and kept in special boxes. A special magnifying glass with graded scales for depth and temperature is used to read these slides.

BT's provided with water samplers are also available (so called "sea samplers"). These samplers take samples automatically at selected depths during the lowering of the BT. However at present none of the "sea samplers" available is entirely satisfactory: all the water bottles tend to leak, and the samples are relatively small and permit determination only of salinity.

WATER SAMPLES

To extract water samples a rubber tube with a glass tube about 15 cm long in one end is fastened to the tap of the water sampler; the air valve at the upper end of the sampler is then opened and water drawn off. The samples for oxygen determination (and for other gas analyses) are taken first,

followed by those for phosphate and salinity determination. All receiving bottles must be rinsed with a little of the sample water, but care should be taken not to waste water for this purpose when many samples are required.

Samples for oxygen determination are run into 250 ml. dark bottles fitted with special glass stoppers. The bottles must be numbered and their volumes known with accuracy. To draw off samples for oxygen test, the glass tube should be very close to the bottom of the receiving bottle and the water run in slowly, care being taken that no bubbles of air enter the water. The glass tube is then slowly lifted while the water is still running. The glass stopper is inserted when the bottle is full, taking care there are no air bubbles under the stopper. When all samples have been drawn off, manganous sulphate or manganous chloride and potassium iodine solutions are added to the oxygen samples. After half an hour sulphuric acid is added and the sample is shaken.

The samples for phosphate, silicate and nitrate determination are brought to laboratory temperature and frequently the analysis is made on board. If the silicate determinations cannot be done on board immediately after the arrival of the samples, they should be stored in polyethylene bottles. All special samples, taken to determine minor constituents or trace elements used by micro-organizms, should be so preserved that biological action does not continue in the sample and that the suspended matter does not decompose. Special instructions are necessary for this, depending on the nature of the analyses.

Samples for chlorinity titration are run into 200-300 ml bottles fitted with attached stoppers with rubber washers. The bottles should be filled almost completely, leaving only 5-10 ml space under the stopper to allow for expansion. If greater space were left, evaporation and change in chlorinity might take place.

DIRECT DETERMINATION OF DENSITY

Direct determination of salinity, usually by measuring the density, can be undertaken in cases where great variations occur, as in brackish water. The accuracy is usually in the range of $\pm$ 0.05% of salinity.

There are several types of Temperature-Salinity-Depth (T.S.D.) recorders. These instruments work on the principle of the changes of electrical conductivity with salinity and temperature. They record the T.S.D. automatically on paper when the instrument is lowered into the water. They can be used only in brackish water and in the upper 100 m .

Salinity determinations are also made by refractometers (Fig. 21), but only in brackish water, and the method needs considerable optical practice. The cheapest and simplest method to determine salinity in brackish water

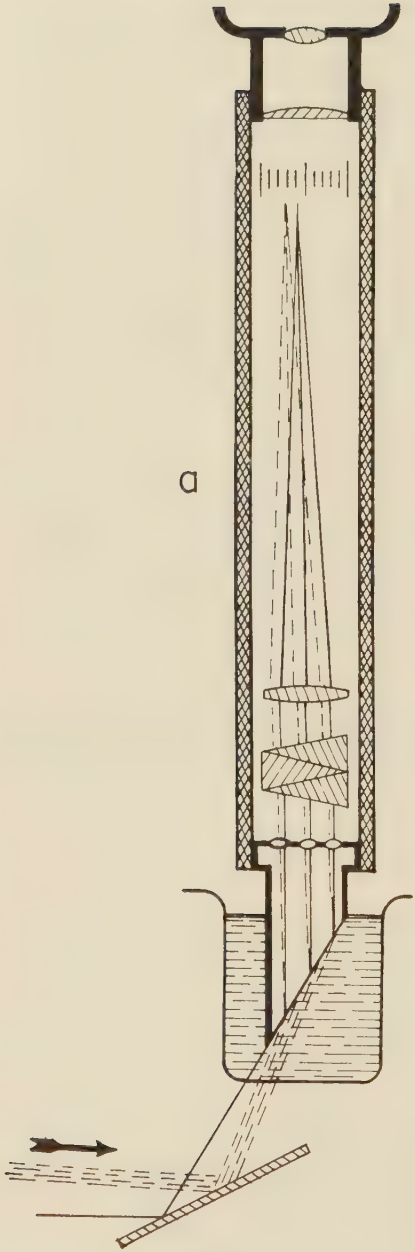
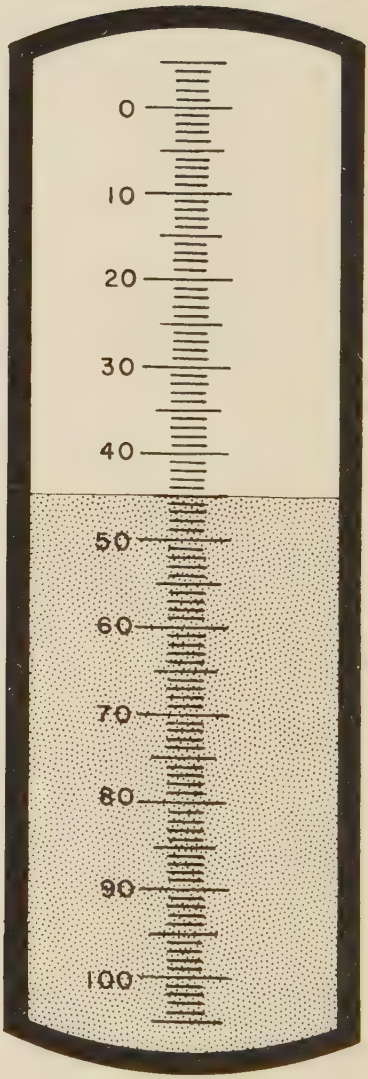


Figure 21 - Refractometer



Reading scale

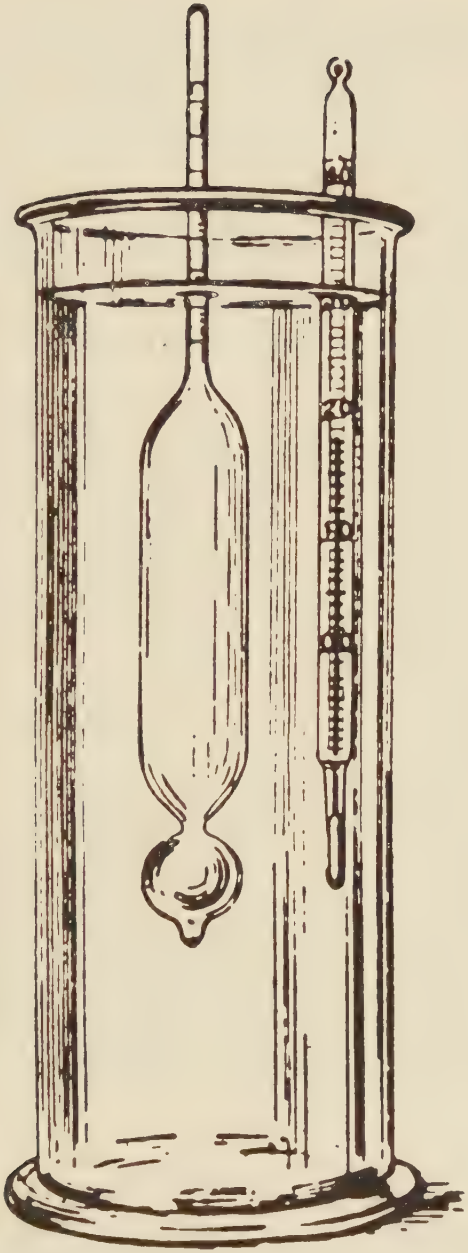


Figure 22 - Areometer

is with properly calibrated areometers (Fig. 22), the reading of which can be converted to chlorinities and salinities by reference to Knudsen tables, temperature having been measured.

4.2.3 **Bathymetry**

When soundings are made, especially in shallow water, the state of the tides must be considered or the time of sounding noted so that tide correction can be made in referring the depth to a standard level.

SOUNDING WITH LEAD AND LINE

Sounding with lead and line is done only in very shallow water. The line must be marked in metres or in fathoms and feet. These calibrations must be checked for accuracy after the line has been wetted and stretched. Table 17 gives fathom and metre equivalents. Care must be taken that the line is not at a great angle when taking depth soundings. There are several types of special leads for sounding. Care should be taken that the cable tension is correct: this can be checked with a special feeler. If the lead has a short tube fitted with a top valve, a small sediment sample can be obtained when sounding, and information obtained about the nature of the sea bottom.

SOUNDING BY PRESSURE

This method has the advantage that soundings can be made with it while under way. The most commonly used pressure instrument is the Thompson sounder. The basis of the Thomson sounder is a vertical glass tube about 610 mm long, closed at the top and coated inside with silver chromate which changes in colour from red to grey-yellow on contact with sea water. The deeper the tube sinks the greater the pressure and the higher the water rises in the tube against the contained air. The length of silver chromate wetted gives a measure of the pressure and therefore of the depth. Table 16 shows the conversion factors. Before use, the tubes should be brought approximately to the same temperature at the bottom water. When taken out from the holder after arriving on board, the tubes should be kept in a vertical position.

OTHER SOUNDERS

Several sounders use explosives which detonate on hitting the sea bottom, but they are rather expensive and usually need a special listening apparatus. The time taken to reach the bottom, sinking velocity being constant, indicates the depth.

ECHOSOUNDERS

Echosounders are among the most essential instruments in present day fisheries research. They are used not only for determination of depth, in trawling operations, but are also used for scouting of fish schools. They can be used for determination of concentration of plankton and for a variety of other purposes. Besides vertical types, horizontal types, the so-called fish-lupes, are available and are specially adapted for fish searching. Detailed descriptions of echo-sounders and asdic for fishing purposes can be found in references at the end of this chapter. The operation of the units is described in manuals provided by the manufacturers; their maintenance is a specialist task lying beyond the responsibility of fishery field officers.

BOTTOM SAMPLING

Investigations on marine sediments often require bottom samples larger than those taken when sounding. There are several types of bottom sampler, depending on the kind of sample required and on the depth of water and nature of the sediment. No satisfactory sampler exists for use on hard bottoms. Taking and processing samples for benthos analysis is described in Section 5.3. Sediment samples are usually preserved in glass jars (1/4 to 1/2 liter) well corked and labelled.

Spring-loaded crabs and orange-peel samplers for sampling the sediment surface are commonly used (Fig. 24). For taking short sediment cores there are various gravity corers (Fig. 25), the effective tube length being usually 60-100 cm. These have removable liners, of cellophane or plastic, in which the samples can be preserved by corking at both ends. The tubes should be properly labelled, preferably with pens specially designed for the purpose. Paper labels are not good for use at sea because they easily become wetted and lost. Care must be taken that the valves and core catchers work properly. To obtain the maximum length of core the weight of the sampler and the lowering and hauling speeds must be adjusted to suit the nature of the sediment. There are several types of Kullenberg corers (piston corers) for taking long cores. The handling of these instruments needs special care and practice which varies according to the type used.

The codes and symbols given in Table 18 are suggested for use in recording the nature of the bottom substrata (type, consistency, colour) in logs or on charts.

4.2.4 Currents

Whenever possible, surface currents should be observed and recorded in the scientific logs. Allowances must be made in coastal waters for tidal currents which are superimposed on permanent or temporary currents caused by other phenomena such as wind. There are several methods, direct and indirect, for measuring and estimating currents.

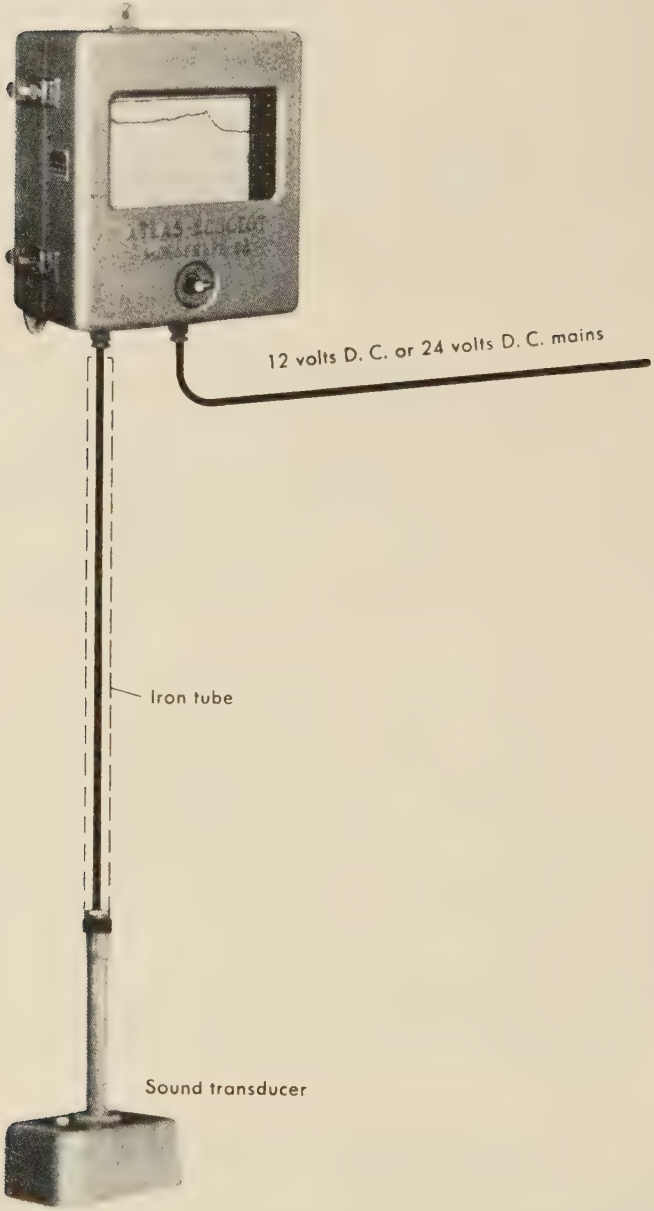


Figure 23 - Echosounder (Courtesy Atlas-Werke, Bremen, Germany)

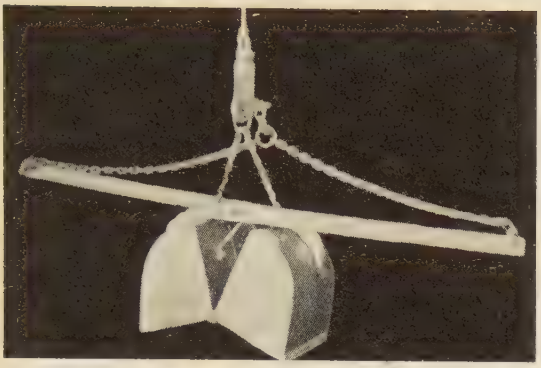


Figure 24 - Bottom grab (Courtesy Laboratoire Océanographique, Charlottenlund, Denmark)

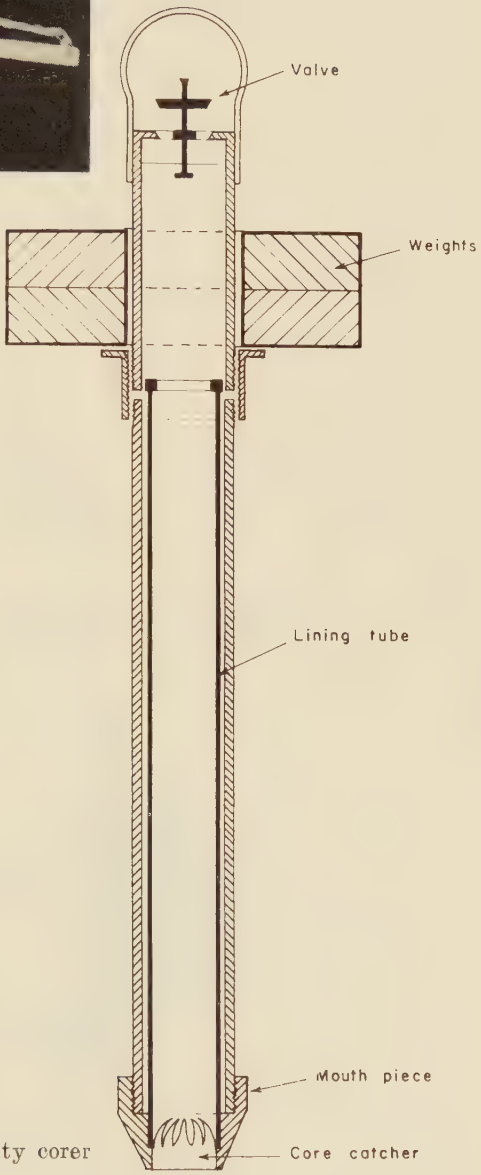


Figure 25 - Gravity corer

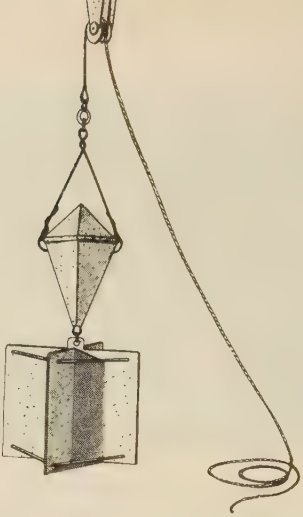
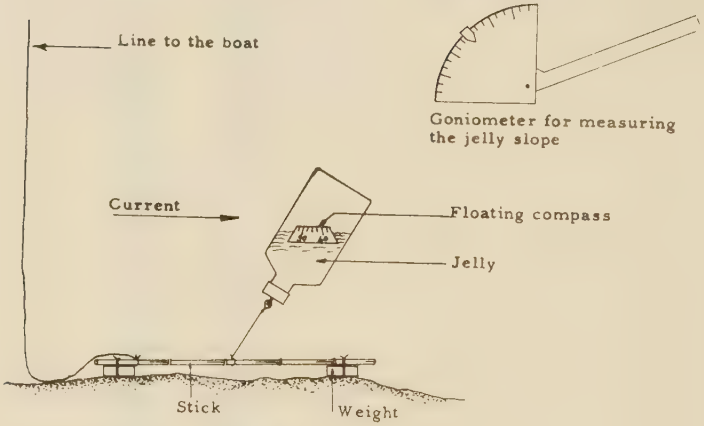


Figure 26 - Current cross

Figure 27 - Jelly bottle



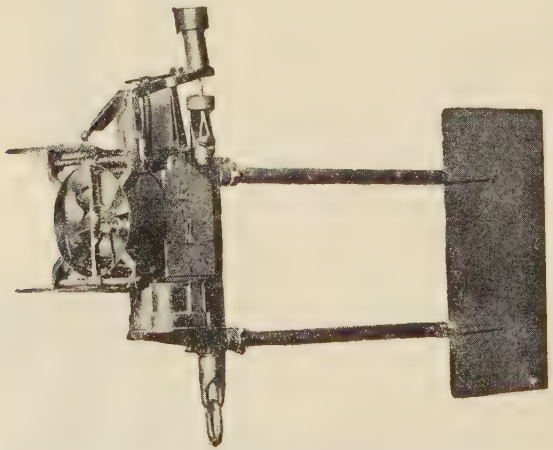


Figure 28 - Current meter (Courtesy Bergen Nautic, Bergen, Norway)

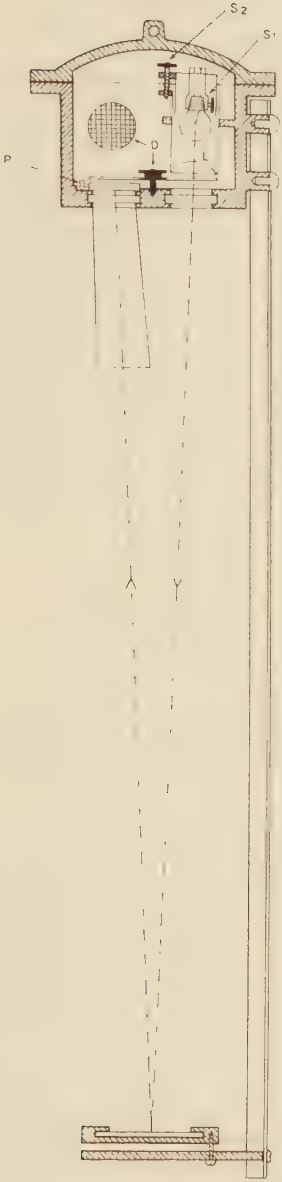


Figure 29 - Plan of the transparency-meter

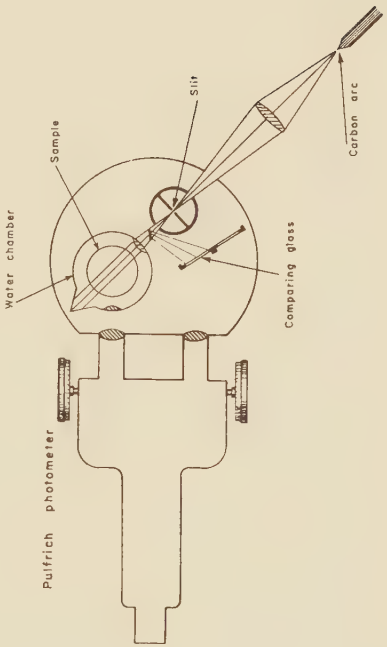


Figure 30 - Tyndall meter

The direction and relative velocity of currents can be determined visually by observing the sea surface around anchored buoys. single small rocks, or similar objects. The accumulation of floating destritus on the surface sometimes gives an indication of the convergence lines of currents, The cheapest and simplest equipment for current observation from anchored vessels is a current cross (Fig. 26). The line to which a cross is attached must be light in weight and marked in meters or fathoms. The length of line pulled out by the current cross per unit time gives the speed: direction is estimated from the direction of the li ne. When measuring subsurface currents with current crosses the area of the cross must be much larger than the surface of the buoy from which the cross is suspended. At night the buoy can be equipped with light. If the vessel is equipped with radar, a radar reflector on the buoy will facilitate the operation. There are several types of direct reading *current meters* for use on anchored ships. If only one anchor is being used, the swinging of the ship around the anchor must be taken into account and the measurements taken several times. In areas with tidal currents the measurements should be made at intervals during at least two tidal periods.

The Carruthers simple current meter uses a bottle, half filled with jelly and a compass floating in it. This meter is especially useful for measuring bottom currents. The bottles are seat down fixed to a weight or to a special neutrally buoyant holder in the desired depth by means of anchored buoys. The jelly bottle is tilted by the current, the cold water solidifies the jelly and the amount of tilt gives, from calibration tables, the current speed. The compass gives the direction of tilt, hence the direction of current. (See Fig. 27.)

The Ekman current meter (Fig. 28) - the most common in use in the past - needs careful handling. The operator must check that the propeller turns in friction-free manner and that the release and closing mechanisms work properly. Sufficient weight below the meter should be used to keep the meter horizontal in the water, otherwise the special compass in the meter will not function properly. Movement of the ship in waves causes considerable errors in the Ekman and other propeller-type current meters suspended from the ship.

Continuous current meters are available, which record currents and their direction for two weeks. These are suspended in the water by buoys and anchors. There are also several other types of simple current meters, such as Carruthers current cones, etc. A more expensive and complicated instrument for measuring surface currents is the Geomagnetic Electro Kinematograph (G.E.K.). This works on the principle that an electric current is induced when a body of water moves in the earth's magnetic field. Special skill is needed for handling this instrument.

4.2.4.2 INDIRECT METHODS OF CURRENT MEASUREMENT

In offshore waters currents may be computed from the drift of the ship. This drift is determined by the difference in unit time of the fix of the ship estimated from its course and speed and the astronomic fix. Drift cards and drift bottles are often used. The bottles are filled with sand so that when floating only a small part of the neck projets through the surface. A card is enclosed in the bottle with a number and the address to which the finder should send the card and a request to the finder to record the date and location of discovery of the bottle. The place and date of release and number are recorded and compared with place and date of recovery. Drift bottles are generally used in semi-closed basins to investigate special features of the surface currents. They give only a rough picture of current paths. The bottles are influenced by winds and waves and these and other factors must be considered when evaluating the results.

Conclusions about the current patterns can also be drawn from "ecological indicators" (mainly plankton and suspended matter).

4.2.5 **Turbidity**

Measures of turbidity are an indication of the amount of suspended matter, including plankton, in the sea water. Changes of turbidity often indicate changes of water masses and convergence lines.

Turbidity measurements are made either visually or with optical instruments. The white, 30 to 35 cm diameter, Secchi disc is used for visual estimates. It is lowered into the water, on the shadow side of the vessel, attached to a line marked in metres or feet. The depth at which the disc disappears from sight is recorded. The disc should be moved slowly up and down at this depth in order to determine the exact depth of disappearance. The depth is usually converted into extinction coefficients: $x = 1.7/D$ where x = extinction coefficient; D = maximum depth of visibility of Secchi disc (in m).

The extinction coefficient can also be measured with electrical extinction meters lowered into the water (Fig. 29). These instruments have an electric light in one end and a photocell at a distance of 60 cm to 2 m at the opposite end. The readings of the photocell are converted either into the percentage of light intensity as compared with clean water, or into an extinction coefficient. The latter should be recorded. These instruments need careful attention and special study. For example the light source must be constant and the window clean and dry on the inside, drying chemicals (e.g. silicagel) are used for this purpose.

Quantitative and qualitative study of suspended matter in sea water can also be made by taking water samples from different depth. The samples must be analysed immediately on arrival on board.

4.2.6. Some references on oceanographical observation practices

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4.2.7 Explanation of terms in Section 4.2

Bathymetry - Measurement of the depth at which the bottom and objects on it lie below the surface.

Bearing - The direction in which an object, or position, lies from an observer.

Brackish water - Water with salinity lower than that of normal sea water (usually below 30% S).

Chlorinity - Amount of chlorine and other halids in one kilogram of sea water, in grams.

Convergence - The meeting of ocean currents or two air masses.

Detritus - Any loose material; usually the remains of plants and animals after disintegration or wearing away.

Diatom - Small (often microscopic) plant (algae), freely floating in sea water. Has small silicious shells which after deposition can form diatom ooze.

Divergence - The opposite to convergence. Moving away from each other.

Drift ice - Numerous small pieces of floating ice of which the total area is less than that of the total water area in which the ice lies.

Echo-sounder - An electrically operated instrument that omits a sound from a vessel's submerged surface and then measures the time interval until the return of the echo, and converts this time interval into an estimate of the distance between the emitter and the object by which the sound has been reflected.

Extinction coefficient - The rate that light intensity decreases with distance in water.

Fix - The position of a ship when found by the intersection of two or more position lines.

Foraminifera - Very small "elementary" animals which live in small calcareous shell, formed by themselves. If these shells are deposited on the sea floor in large amounts they form foraminifera ooze (also called globigerina ooze).

Gravel - Mineral particles 2 - 4 mm in diameter.

Hydrography - The science and practice of surveying oceans and seas. It excludes biological matter.

Messenger - A metal weight which is sent down on cables to manipulate suspended instruments.

Ocular - The eyepiece of an optical instrument.

Pack ice - Numbers of large pieces of floating ice that have come together and lie more or less in contact.

Pebble - Mineral particles (stones) with a diameter of 4 - 64 mm.

Phosphate - A salt or ester of phosphoric acid, or a negative ion containing phosphorus and oxygen (PO_4). A very important nutrient salt in the sea.

Photocell - A cell or a vacuum tube whose electrical properties are modified by the action of light.

Pteropod - Small planktonic gastropod mollusc.

Quartz - A form of silica (SiO_2), usually colourless and transparent.

Radiolarian - A minute marine rhizopod having a siliceous skeleton.

Refractometer - Any of various instruments used for measuring refraction.

Salinity - The number indicating the amount of salts, in grams, in a kilogram of sea water when all the carbonate has been converted to oxide, the bromine and iodine replaced by chlorine, and all organic matter completely oxidized.

Sand - Mineral particles with a diameter of 1/16 - 2 mm.

Tyndall effect - Back scattering of light from minute particles suspended in the air or water.

Titration - A method or process to determine the strength of a solution or the concentration of a substance in solution, in terms of the smallest amount of it required to bring about a given effect in reaction with another known solution or substance.

Trace element - Elements occurring in natural waters and in organisms in minute quantities.

Turbidity - Cloudiness of a solution caused by suspended matter.

Yellow substance - Brownish coloured organic compounds of unknown composition (related to humic acid) occurring in natural waters and derived from the decomposition of organic matter.

Table 11

Code for reporting sea condition

Code figure		Height	
		meters	feet (approx.)
0	Calm–glassy	0	0
1	Calm–rippled	0 – 0.1	0 – 1/3
2	Smooth–wavelets	0.1 – 0.5	1/3 – 1 2/3
3	Slight	0.5 – 1.25	1 2/3 – 4
4	Moderate	1.25 – 2.5	4 – 8
5	Rough	2.5 – 4	8 – 13
6	Very rough	4 – 6	13 – 20
7	High	6 – 9	20 – 30
8	Very high	9 – 14	30 – 45
9	Phenomenal	over 14	over 45

Table 12

Specifications for swell

Length		
Short	0 – 300 feet	0 – 100 m
Average	300 – 600 »	100 – 200 m
Long	> 600 »	> 200 m
Height		
Low	0 – 7 feet	0 – 2 m
Moderate	7 – 13 »	2 – 4 m
Heavy	> 13	> 4 m

Table 13

Code for reporting the state of the ice

0	Ice-free
1	Loose ice or new ice
2	Fast ice (up to 15 cm)
3	Drift ice (floes up to 15 cm)
4	Pieces of ice pressed together (ice breccia), or tight drift ice (raffed ice)
5	Open water along the coast
6	Strong fast ice ($>$ 15 cm thick)
7	Strong drift ice ($>$ 15 cm thick)
8	Pack ice
9	Ice pressure
10	Unknown

Table 14

Ice code for shipping

(*Baltic Code*)

0	Free for all shipping
1	Free for steamers; difficult for sailing ships
2	Difficult for steamers; closed for sailing ships
3	Possible for powerful steamers
4	Possible only for steamers with ice protection
5	Possible with icebreakers
6	Open way in ice exists (made by icebreakers)
7	Shipping temporarily stopped
8	Shipping stopped
9	Shipping possibilities not known, (e.g. because of visibility)
10	No report

Table 15

Forel water colour scale code

Code	Description
00	Deep blue.
10	Blue.
20	Greenish-blue (or green blue).
30	Bluish-green (or blue green).
40	Green.
50	Light green.
60	Yellowish-green.
70	Yellow-green.
80	Green yellow.
90	Greenish-yellow.
99	Yellow.

Table 16

The Thompson sounder

Red part, in mm	Depth in m	Red part, in mm	Depth in m
296	10	120	42
284	11	116	44
273	12	112	46
262	13	103	48
253	14	104	50
244	15	101	52
235	16	98	54
227	17	95	56
220	18	92	58
213	19	90	60
207	20	84	65
194	22	79	70
183	24	74	75
173	26	70	80
164	28	66	85
156	30	63	90
149	32	60	95
142	34	57	100
136	36	55	105
130	38		
125	40		

Table 17

Depth conversion - Fathoms to metres

Fathoms	0	1	2	3	4	5	6	7	8	9
0.....	0.0	1.8	3.7	5.5	7.3	9.1	11.0	12.8	14.6	16.5
10.....	18.3	20.1	21.9	23.8	25.6	27.4	29.3	31.1	32.9	34.7
20.....	36.6	38.4	40.2	42.1	43.9	45.7	47.5	49.4	51.2	53.0
30.....	54.9	56.7	58.5	60.3	62.2	64.0	65.8	67.7	69.5	71.3
40.....	73.2	75.0	76.8	78.6	80.5	82.3	84.1	86.0	87.8	89.6
50.....	91.4	93.3	95.1	96.9	98.8	100.6	102.4	104.2	106.1	107.9
60.....	109.7	111.6	113.4	115.2	117.0	118.9	120.7	122.5	124.4	126.2
70.....	128.0	129.8	131.7	133.5	135.3	137.2	139.0	140.8	142.6	144.5
80.....	146.3	148.1	150.0	151.8	153.6	155.4	157.3	159.1	160.9	162.8
90.....	164.6	166.4	168.2	170.1	171.9	173.7	175.6	177.4	179.2	181.0
100.....	182.9	184.7	186.5	188.4	190.2	192.0	193.8	195.7	197.5	199.3
110.....	201.2	203.0	204.8	206.7	208.5	210.3	212.1	214.0	215.8	217.6
120.....	219.5	221.3	223.1	224.9	226.9	228.6	230.4	232.3	234.1	235.9
130.....	237.7	239.6	241.4	243.2	245.1	246.9	248.7	250.5	252.4	254.2
140.....	256.0	257.9	259.7	261.5	263.3	265.2	267.0	268.8	270.7	272.5
150.....	274.3	276.1	278.0	279.8	281.6	283.5	285.3	287.1	288.9	290.8
160.....	292.6	294.4	296.3	298.1	299.9	301.7	303.6	305.4	307.2	309.1
170.....	310.9	312.7	314.5	316.4	318.2	320.0	321.9	323.7	325.5	327.3
180.....	329.2	331.0	332.8	334.7	336.5	338.3	340.2	342.0	343.8	345.6
190.....	347.5	349.3	351.1	353.0	354.8	356.6	358.4	360.3	362.1	363.9
200.....	365.8	367.6	369.4	371.2	373.1	374.9	376.7	378.6	380.4	382.2
210.....	384.0	385.9	387.7	389.5	391.4	393.2	395.0	396.8	398.7	400.5
220.....	402.3	404.2	406.0	407.8	409.6	411.5	413.3	415.1	417.0	418.8
230.....	420.6	422.4	424.3	426.1	427.9	429.8	431.6	433.4	435.2	437.1
240.....	438.9	440.7	442.6	444.4	446.2	448.0	449.9	451.7	453.5	455.4
250.....	457.2	459.0	460.1	462.7	464.5	466.3	468.2	470.0	471.8	473.7
260.....	475.5	477.3	479.1	481.0	482.7	484.6	486.5	488.3	490.1	491.9
270.....	493.8	495.6	497.4	499.3	501.1	502.9	504.7	506.6	508.4	510.2
280.....	512.1	513.9	515.7	517.5	519.4	521.2	523.0	524.9	526.7	528.5
290.....	530.3	532.2	534.0	535.8	537.7	539.5	541.3	543.1	545.0	546.8

Fathoms	0	10	20	30	40	50	60	70	80	90
300.....	549	567	585	603	622	640	658	677	695	713
400.....	732	750	768	786	805	823	841	860	878	896
500.....	914	933	951	969	988	1,006	1,024	1,042	1,061	1,079
600.....	1,097	1,116	1,134	1,152	1,170	1,189	1,207	1,225	1,244	1,262
700.....	1,280	1,298	1,317	1,335	1,353	1,372	1,390	1,408	1,426	1,445
800.....	1,463	1,481	1,500	1,518	1,536	1,554	1,573	1,591	1,609	1,628
900.....	1,646	1,664	1,682	1,701	1,719	1,737	1,756	1,774	1,792	1,810

Fathoms	0	100	200	300	400	500	600	700	800	900
1,000....	1,829	2,012	2,195	2,377	2,560	2,743	2,926	3,109	3,292	3,475
2,000....	3,658	3,840	4,023	4,206	4,389	4,572	4,755	4,938	5,121	5,303
3,000....	5,486	5,669	5,852	6,035	6,218	6,401	6,584	6,766	6,949	7,132
4,000....	7,315	7,498	7,681	7,864	8,047	8,229	8,412	8,595	8,778	8,961
5,000....	9,144	9,327	9,510	9,692	9,875	10,058	10,241	10,424	10,607	10,790
6,000....	10,973	11,155	11,338	11,521	11,704	11,887	12,070	12,253	12,436	12,618
7,000....	12,801	12,984	13,167	13,350	13,533	13,716	13,899	14,082	14,264	14,447
8,000....	14,630	14,813	14,996	15,179	15,362	15,545	15,727	15,910	16,093	16,276
9,000....	16,459	16,642	16,825	17,008	17,190	17,373	17,556	17,339	17,922	18,105

Table 18

Notations for the nature of the bottom

Blue	b.	Mud	M.
Black	bl.	Mussels	Ms.
Brown	br.	Ooze	Oz.
Coarse	c.	Pebbles	P.
Calcareous	ca.	Pteropod	pt.
Chalk	Ck.	Pumice	Pm.
Clay	Cy.	Quartz	Qz.
Coral	Co.	Rock	R.
Dark	d.	Radiolaria	Rd.
Diatom	Di.	Red	rd.
Fine	f.	Sand	S.
Foraminifera	Fr.	Soft	so.
Gravel	Gr.	Shells	Sh.
Green	gn.	Small	sm.
Ground	Gn.	Stone	St.
Grey	gy.	Stiff	sf.
Glacial	ga.	Sticky	sy.
Hard	h.	Volcanic	v.
Large	l.	White	w.
Lava	Lv.	Weed	Wd.
Light	Lt.	Yellow	y.

Table 19

Length in metres of cable required to reach calculated depths at certain wire angles

Calculated depth (in metres)	Wire angle												
	20°	25°	30°	35°	40°	45°	50°	55°	60°	65°	70°	75°	80°
50	53	55	58	61	65	71	78	87	100	118	146	193	288
100	106	110	116	122	130	141	156	174	200	237	292	386	576
150	160	165	173	183	196	212	233	261	300	355	439	580	864
200	213	221	231	244	261	283	311	349	400	473	585	773	1152
250	266	276	289	305	326	354	389	436	500	592	731	966	1440
300	319	331	346	366	392	424	467	523	600	710	877	1159	1728
350	372	386	404	427	457	495	545	610	700	828	1023	1352	2016
400	426	441	462	488	522	566	622	697	800	946	1170	1546	2304
450	479	496	520	549	587	636	700	784	900	1065	1316	1739	2592
500	532	552	596	610	652	707	778	872	1000	1183	1462	1932	2880
550	585	607	635	672	718	778	856	959	1100	1301	1608	2125	3167
600	638	662	693	733	783	848	934	1046	1200	1420	1754	2318	3455
650	692	717	751	794	848	919	1011	1133	1300	1538	1901	2512	3743
700	745	772	808	855	914	990	1089	1220	1400	1656	2047	2705	4031
750	798	827	886	916	979	1060	1167	1307	1500	1774	2193	2898	4319
800	851	882	924	977	1044	1131	1245	1394	1600	1893	2339	3091	4607
850	904	938	982	1038	1109	1202	1323	1482	1700	2011	2485	3284	4895
900	958	993	1040	1099	1174	1273	1400	1569	1800	2129	2632	2478	5183
950	1011	1048	1097	1160	1240	1343	1478	1565	1900	2248	2778	3671	5471
1000	1064	1103	1155	1221	1305	1414	1556	1743	2000	2366	2924	3864	5759

Form 8

Primary Oceanographic Data Sheet

a Cruise	b Station	c Latitude	d Longitude	e Wind Force	f Sonic Depth	g Colour of the Sea	h Cast	i Wire Angle	j Start (GCT)	k Messenger		
										l Down (GCT)	m Up (GCT)	n In (GCT)

o Vessel (name)	p Date (GCT)	q Sea	r Bottom Type	s Transparency	t BT Slide No.	u Observer

1 Des. Depth m	2 Meter wheel	3 Thermometric depth	4 Wire depth	5 Sample bottle No.					6 Sampler (Nansen bottle) No.	7 Thermometer Left		8 Thermometer Right		9 Remarks
				5.1 $Cl^{0}/_{00}$	5.2 O_2	5.3 PO_4	5.4	5.5		7.1 Main	7.2 Aux.	8.1 Main	8.2 Aux.	

NOTES ON FORM 8: PRIMARY OCEANOGRAPHIC DATA SHEET

This sheet is completed (with a carbon copy) for every hydrographic station at which water samples from below surface are taken.

c/d– Instead of latidude and longitude a descriptive position or a number or letter for routine stations can be given in coastal waters if the exact position of the station is clearly indicated on the chart and in the Cruise and Station Log, but only provided these other records are easily accessible to those using this sheet.

o– Give wind force only. Other meteorological data are entered in the met data sheet, which is usually kept on the bridge.

f– Give the depth obtained as with the echo-sounder (or by other sounding. If this is not possible, enter the depth as indicated on the sea chart.

g– State the colour of the sea according to the Forel scale.

h to n – Give the number of hydrographic casts, wire angle before sending the messenger for closing the bottles and the times for *starting* the cast, when messenger is sent *down*, when the heaving *up* is started and when all bottles are *in*.

q – Give the state of the sea, coded (see 4.1).

r – Give the coded description of sediment or type of bottom if sample obtained, or the type of bottom if otherwise ascertained (e.g. from sea charts, sediments fastened on weight, etc.).

s – Give the transparency, as obtained by the Secchi disc.

2 – Give the meter wheel readings when lowering the cast.

3 – Thermometric depth as determined later from the difference between the unprotected and protected temperature readings.

4 – Wire depth as determined from the meter wheel reading and wire angle. (See Table 19.)

5 – Give the numbers of the sample bottles.

6 – Give the numbers of Nansen bottles (or other water samplers used).

7/8 – Enter the readings of the thermometers.

9 – Remarks should include any misbehaviour of thermometers and other items of interest. The numbers of salinity boxes, amount of roll of vessel, etc. should also be noted here.

Form 9

Thermometer Arrangement Sheet

Vessel name a Cruise No.	b Stations on which thermometers have been used in this arrangement First Station No..... Last Station No..... Date ..... Date						c. Preparation of Arrangement By..... on (date)	
1 Nansen Bottle No.	2 Left Thermometer			3 Right Thermometer				d Arrangement changed by e Date and Hour
	2.1 P.No.	2.2 V_0	2.3 I	3.1 U.No.	3.2 V_0	3.3 I	3.4 1/Q m Factor	f Checked by Date
								g Remarks

NOTES ON FORM 9: THERMOMETER ARRANGEMENT SHEET

A thermometer arrangement sheet is prepared in duplicate before every cruise or when the arrangement is changed during the cruise.

When a thermometer fails to function properly and is replaced, a new arrangement sheet must be completed.

c/d – Give the date when the sheet is prepared and the name of the arranger.

b/e – Give the numbers of stations and the dates where and when this arrangement is used.

f/g – Indicate the date and hour when this arrangement is changed and a new sheet is prepared.

2.1 – P. No. - Number of protected thermometer.

3.1 – U. No. - Number of unprotected thermometer.

2.2/3.2 – V_o - The mercury volume at 0°C. (Obtained from the thermometer calibration sheet).

2.3/3.3 – I - Index correction of the main thermometer scale. (Obtained from the thermometer calibration sheet).

3.4 – 1/Q m. - The "pressure factor" for unprotected thermometers.

Form 10

Chlorinity and Salinity Determination Sheet

a) Vessel	b) Cruise	c) Station	d) Chemist	e) Date Analyzed	f) Checked by

1 Serial Number	2 Sample Bottle Number	3 1st Burette Reading	4 2nd Burette Reading	5 Average Burette Reading	6 K	7 Chlorinity ‰	8 Salinity ‰	9 STANDARDIZATION (N)-(A)=a			10 Remarks
								9.1 Cl ‰ of Standard (N)	9.2 Amount of $AgNO_3$	9.3 a	

NOTES ON FORM 10: CHLORINITY AND SALINITY DETERMINATION SHEET

3/4/5 – Give the readings of two titrations and compute the average.

6 – K is given in Knudsen tables if a is known.

7/8 – Average burette reading and K gives the chlorinity; salinity is taken from Knudsen tables.

9 – a is computed as the difference between the chlorinity of a standard sea water sampler and the burette reading for the titration reading of this standard water.

Form 11

Chemical Data Sheet (Oxygen, Phosphates)

a Standardization	b Remarks	c Cell Checks	d Vessel and Cruise
1			
2	c Analyst	f Remarks	g Station
3			
h Normality of $Na_2S_2O_3$	i Date		j Analyst

1 Nominal Depth	2 Bottle No.	3 Burette Reading 3.1 1	3 Burette Reading 3.2 2	4 Temp.	5 S‰	6 Sat. O_2 ml/L	7 %Sat.	8 Conc. ml/L	9 True depth	10 Bottle No.	11 Time Addn.	12 Time Read	13 %T or E	14 Corrected E	15 Conc. µg at/L

NOTES ON FORM 11: CHEMICAL DATA SHEET

(Oxygen, Phosphates)

Notes :-

a/h – Give the titers and the computed normality of sodium thiosulphate.

f – Always indicate the instrument used for phosphate determination.

3 – When using an automatic zero burette, give only one reading.

4/5/9 – Enter the corrected temperature and salinity and true depth from other logs.

6/7 – Enter the oxygen saturation from the tables in the Laboratory Manual, and compute the percentage saturation.

15/(f) – If determining phosphates with Nessler tubes, enter the estimates in the concentration column. Also record the hour when standards in Nessler tubes are made, in the column for remarks.

Form 12

Oceanographic Summary Sheet

a. Vessel ... b. Station c. Date-Time to

d. Latitude ..... e. Longitude ..... f. Depth g. Observer

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Serial	Calc.	Observed		Interpolated													
No.	P	T°C	S‰	D	T°C	S‰	σ_0	$\sigma\sigma_0$	σt	$\Delta s,t$	$\delta t,p$	$\delta s,p$	δ	δ	ΔD	ΣD	

NOTES ON FORM 12: OCEANOGRAPHIC SUMMARY SHEET

Make entries in the heading as indicated, using the name of the vessel from which the samples were taken and the serial station number. Indicate time zone on which times are based (Z for Greenwich; + values for zones west, and - values for zones east of Greenwich). Report latitudes and longitudes in degrees and minutes, with decimal fractions of a minute when such are significant. Report depths in metres.

1 Serial number of observation.

2 Depth, calculated using metre wheel readings, wire angle and protected and unprotected thermometer readings.

3 Temperature for depth given in column 2 as obtained from protected thermometer, fully corrected.

4 Salinity for depth given in column 2.

5 Standard depths for purposes of computation.

6 Temperatures at standard depth as obtained by interpolation from temperature vs. depth curve based on values given in columns 2 and 3.

7 Salinities at standard depths as obtained from salinity vs. depth curve based on values given in columns 2 and 4. (The use of chlorinities in preference to salinities awaits expansion of suitable tables for use in interpolation).

8 As normally defined $0_0 = (C_0\text{-}1)\ 10^3$ where C_0 is the density of the water of the given chlorinity at 0°C under atmospheric pressure. In this column, however, the factor 10^5 is used rather than 10^3 in order to drop the decimal point. Obtain from Knudsen's Tables.

9 $D = 0_0\text{-}0_t$ as obtained from Knudsen's Tables or expansion of same c cf. expanded table of Thompson and Robinson). As in column 8 the factor of 10^5 is used rather than 10^3 in order to drop the decimal point.

10 $0_t = (\sigma_{s,t,o}\ \text{-}1)\ 10^3$ where $\sigma_{s,t,o}$ is the density of the water of given salinity, and t_0C and under atmospheric pressure. Factor of 10^5 rather than 10^3 is used to permit dropping decimal point. 0_t is obtained from columns 8 and 9 or preferably directly from columns 6 and 7 where suitable tables are available to cover temperature-salinity range (see Matthews, Donald J., Tables of the determination of density of sea water under normal pressure, Sigma-t. *Cons. int. Explor. Mer*, 1932, 59 pp.; and La Fond, E. C., 1951, Processing oceanographic data. H.O. Publ. No. 614).

11 Values of $10^5\ \Delta_{s,t}$ as obtained from 0_t, column 10, using Table III, appendix p. 1055 of 'The Oceans'.

12 $10^5\ C_{t,p}$ as obtained from Tables Va and Vb of 'The Oceans' (appendix pp. 1058-1059). (For expansion see La Fond, 1951).

13 $10^5\ \delta_{s,p}$ as obtained from Tables IVa and IVb of 'The Oceans' (appendix pp. 1056-1057). (For expansion see La Fond, 1951).

14 $10^3\ \delta$ as obtained by applying pressure corrections in columns 12 and 13 to base values of $10^5\ \Delta_{s,t}$ given in column 11.

15 Means of 10^5 between successive depths as obtained from column 14.

16 Geopotential anomaly between successive isobaric surfaces expressed in dynamic meters. These values are the product of means of 10^5 (column 15) and corresponding depth increments obtained from successive depth differences in column 5.

17 Cumulative anomalies of dynamic depth (dynamic metres) of the corresponding isobaric surfaces (column 5) summed by adding successive values in column 16. The depth of any isobaric level in dynamic metres can be obtained by adding the anomaly (column 17) to the corresponding values for standard isobaric reference levels given in 'The Oceans' (appendix) Table II, pp. 1054.

Section 5

OBSERVATIONS ON THE ENVIRONMENT

(Biology)

5.0 INTRODUCTION

This chapter gives detailed directions on the collection of biological material other than the species of economic importance, which are dealt with in Chapter 2. A large part of the Chapter deals with collection of plankton, but this should not be taken to mean that planktonic organisms are of greater importance than others: for some investigations they are, for others they may be of no importance.

This Chapter does not deal with the problems of planning field collection work which, in the case of plankton, may be of especial intricacy, but only with the manipulative operations of collection, handling and preservation. However the collection plan is of very considerable importance and should be adhered to as closely as possible; each expedition plan should contain instructions not only as to places and times of collection, but also as to the modifications of this plan that should be introduced if and when necessary.

Plankton collection methods are of two principal kinds: those that take plankton from samples of water, and those that place collecting equipment in the sea and take samples of plankton from the open sea. The latter then fall into two classes: those that take single samples and those that make a continuous sampling over an extended traverse.

5.1 PLANKTON

5.1.1 Collection of plankton samples for pigment analysis

Pigment (usually chlorophyll) analyses are used for rapid measurement of the standing crop of plankton. If plankton is collected with millipore filters, the filters can also be used for its taxonomic study if proper preparations are made. The amount of water filtered depends on the amount of plankton present.

(a) *The use of millipore filters.* An exactly measured amount of water is sucked through the millipore filter with a special filtering assembly. Two portions of distilled water (about 20 ml each) are passed through the filter to remove the sea salts, and then it is carefully removed from the assembly, put into a small Petri dish and labelled to show location of sample, amount of water filtered, date. The Petri dishes with filters are placed in a vacuum desiccator, dried and stored in a dark, cold place until sending to the laboratory for further analyses.

(b) *The use of the Foorst plankton centrifuge.* After shaking, the sample 0.5-2 litres) is poured into an aspirator bottle from which a rubber tube fitted with a stopcock leasd to the intake of the Foorst plankton centrifuge. The centrifuge is turned on and the stopcock opened so that one litre flows through the centrifuge in about six minutes. When the last of the sample has flowed throuhg, the bottle is rinsed three times with a strong stream of distilled water. The centrifuge is then stopped and the cup removed. The particulate matter in the cup is scrubbed down with a rubber policeman and rinsed into a 16 or 20 b 125 mm screw-cap test tube; the cup is then rinsed again. The material is then centrifuged at a high speed in a clinical centrifuge for three minutes, the water poured off, and allowed to drain out of the tube. The tube is placed in a vacuum desiccater and dried. It should be sent as soon as possible to the laboratory for analysis.

5.1.2 Collection of plankton by filtration

In filtration methods the plankton is removed from the water by retention on filters. The quality and quantity of the plankton caught depends on the pore size of the filters. In quantitative work the amount of water filtered must be measured or estimeted.

The volumes of water passed through the filters vary from 1 - 100 1. Small quantities are collected with hydrographical water bottles; for large volumes special samplers made of sail cloth are used. The water is filtered through either a small plankton net or special filters, which usually contain two small filter discs made from bolting silk No.3 and No.20. The coarse No.3 filter retains mainly zooplankton and the fine No.20 mainly large phytoplankton organisms. In this way a separation into two components can be made in the initial stage of sampling. The small discs with the retained material are usually removed from the apparatus and preserved entire in neutralised formaline, whereas plankton on the large filters is washed into containers and preserved.

Pumping the water from given depth and passing it through nets or filters is also used to obtain samples. When the emphasis is on zooplankton, at least 500 1 of water must be pumped through the nets for reliable results. The pumping method is reasonably satisfactory when investigating the stratification of plankton in the upper 100 metres; technical difficulties with the suction pipe limit this method to this depth range; furthermore, the organisms are often damaged on the filters by forcing water through them at relatively high pressure.

5.1.3. Collection of plankton by precipitation

The water sample (0.5 - 2 1) is put into a bottle and 30 - 50 ml of sodium carbonate solution (50 g of sodium carbonate per 1) is added per 1 of sea water. The magnesium precipitate formed is allowed to settle for approxi-

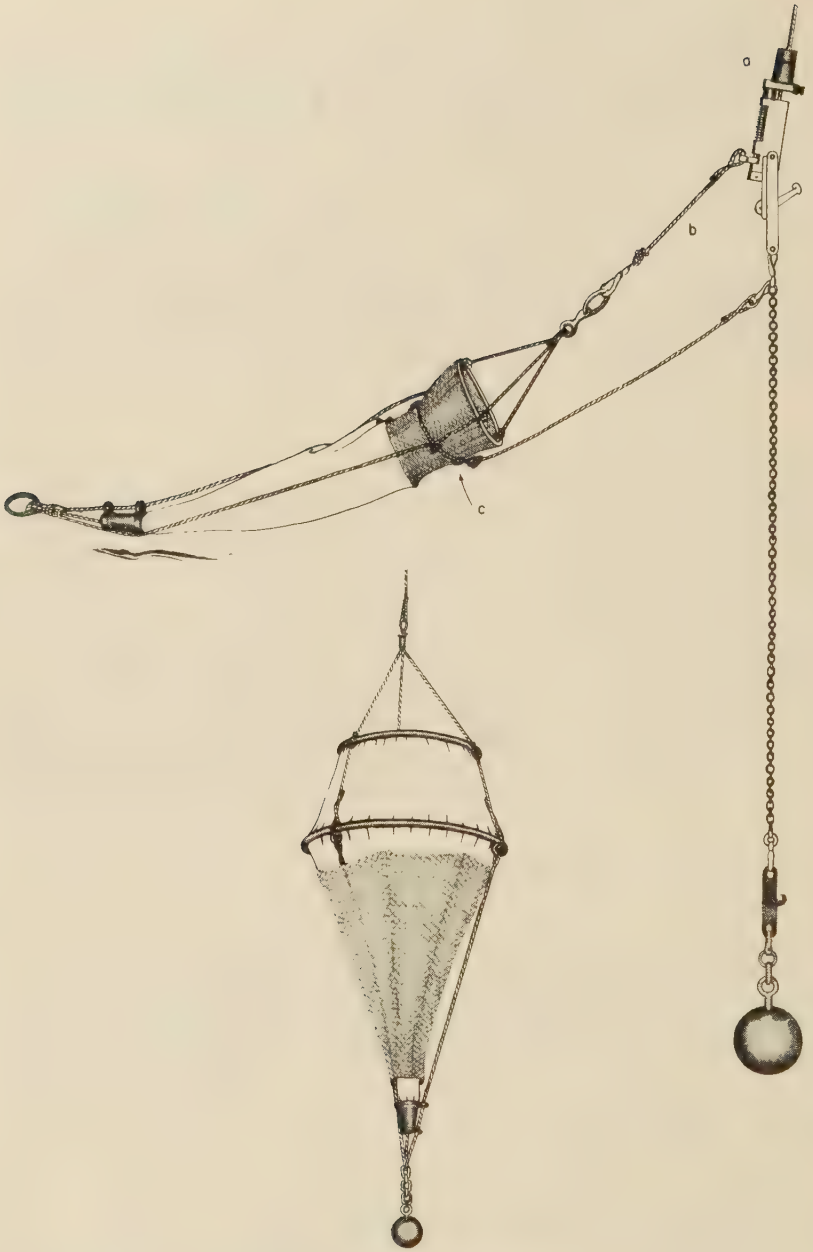

Figure 31. - Plankton nets
(Courtesy Laboratoire Océanographique, Carlottenlund, Denmark)

mately 12 hours. The clear liquid is then syphoned off and the precipitate passed through fine filters such as a millipore filter. The precipitate is dissolved in small amounts of very dilute hydrochloric acid and preserved with neutralised formalin. This sample is later investigated in the laboratory by the sedimentation method.

5.1.4 Collection of plankton with nets

Nets, of which there are many different types, are among the instruments most used for qualitative and quantitative investigation of plankton. The most common types are listed in Table 20. Besides those given in the table there are many others of special construction, such as closing nets, high speed nets, etc. The net catches are influenced mainly by the following factors which depend directly on the instruments or on the methods used:

(1) The opening diameter and the effective filtration of the net;

(2) Hauling speed;

(3) Duration of the haul;

(4) Losses due to insufficient washing of the nets and accidents with bottling samples, etc.

The most commonly used net sizes are as follows:

Bolting Silk No.	Size of aperture	Mesh per inch	Principal groups of organisms caught.
2	0.37	54	Large planktonic forms (macroplankton), no larval stages;
6	0.24	74	Intermediate plankton forms (mesoplankton), some larval stages, some diatoms;
12	0.12	125	Small adult plankton (mesoplankton and part of microplankton), all larval forms, most large diatoms.
20 and 25	0.076 and 0.064	173 and 200	All larval stages large diatoms, and dinoflagellates (microplankton) down to ca 50μ in size.

It must be borne in mind that nets are unsuitable for quantitative phytoplankton research, because the bulk of the phytoplankton passes through them. The filtering capacity of nets smaller in mesh than No.10 is rather low and severe clogging may easily occur, especially when the plankton concentration is high. In this case the duration of the haul is no longer proportional to the amount of plankton caught. It must also be remembered that the mesh size of most net materials changes with its age and the frequency of use.

Plankton nets are hauled both horizontally and vertically. A sample obtained by horizontal hauls is an average over a large area and generally

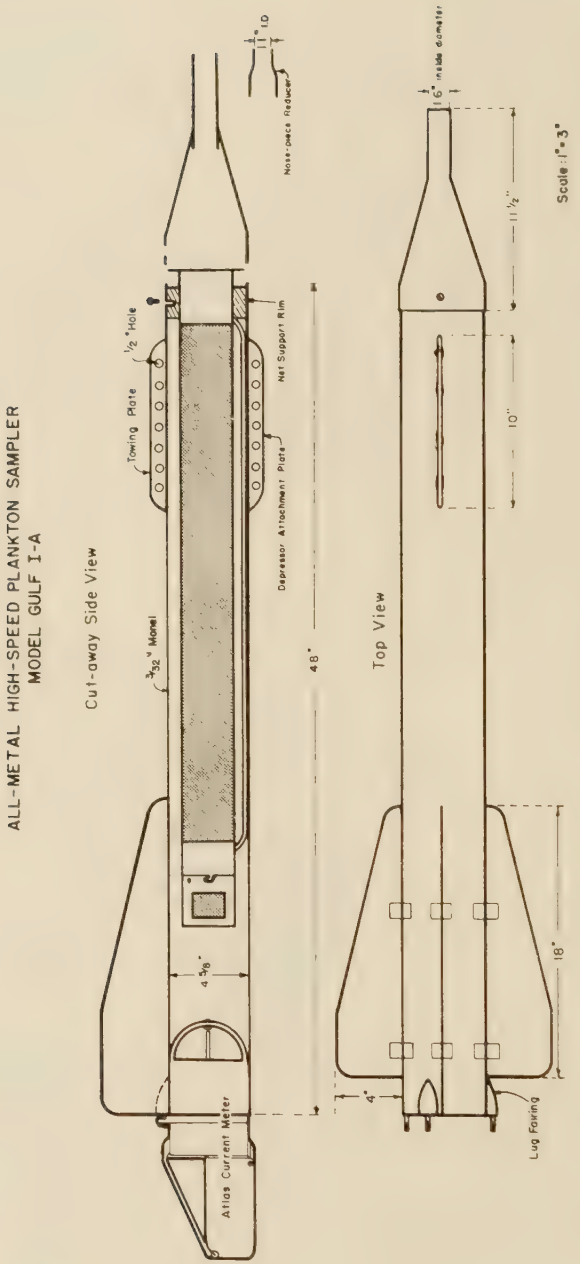

Figure 32. - High speed plankton sampler

gives no information on the patchiness of the plankton. Differences in depth distribution are similarly observed with oblique hauls. On the other hand, it is much more difficult to determine the amount of water filtered by horizontal hauls by vertical hauls, because of the variability of horizontal towing speed. It is easier to estimate the total amount of water filtered with vertical hauls. Closing nets are used to investigate the vertical distribution of plankton. Some workers have pointed out that when the nets are closed part of the sample is usually lost; so these nets must be used withe are.

To overcome the uncertainty about the amount of water that is filtered by the net, Clarke-Bumpus samplers are being used more and more. With this plankton sampler the amount of water passing through the net is measured by a propeller counting device which must be properly calibrated. Several types of this sampler have been constructed in recent years. Nakai has made a twin plankton net for larger phytoplankton and small zooplankton study, the surface of which is relatively large and the net can be easily fitted with a small flow-meter.

Several types of high-speed plankton samplers are available to save time during long periods at sea. All of these are provided with flow-meters to determine the amount of water actually filtered, and they allow plankton to be collected while under way. Furthermore, all fast swimming plankton organisms can be caught with these samplers. These highspeed samplers can therefore be considered as the best instruments for quantitative plankton collection; the most used of them is probably "Gulf I-A". Plankton catches may vary up to + 100% from the average value and a deviation of + 33% can be considered as fairly good.

METHODS OF MAKING PLANKTON HAULS

Make certain that the nets to be used are properly attached to the jib snaps or directly to the rings.

When attaching the bucket to the net and in shackling the net to the cable, be sure that all fittings are tight. A sufficiently heavy weight is attached at the end of the cable (10 to 50 kg depending on the size of the net). Sometimes also small depressors are used below the net. The distance between the net and weight is usually 2 to 4 meters and more in case of long nets.

It is imperative that the ship be on course and at the proper speed before the nets are lowered into the water. The course should be a straight line with the wind on the port bow, unless a strong current dictates another course. This should prevent any drift over the gear. After signaling the bridge to get under way time should be allowed for the ship to come to a towing speed of approximately 1.5 - 2 knots. When lowering the nets into the sea, do so as gently as possible, making certain that the net is not fouled on the ship, that the bridles are not tangled and that the net is opening properly.

At the completion of the tow, when the net reaches the surface, it is picked up by the ring with a block and tackle, hoisted on the gate boom and thoroughly washed down to concentrate the catch into the bucket.

The oblique haul will usually be made with only one net. The three-line bridle of the net is connected to the end of the towing cable by means of a 1-fathom length of 1/4" cable. A 75-lb streamlined weight is suspended from the end of the towing cable also by a 1-fathom length of 1/4 inch cable. Shackles are used in making the connections. Immediately the net is launched, the winch is started and the cable fed out at a slow even rate (30/40 metres per minute) until the net reaches a calculated depth of 200 metres. Then its retrieval is started immediately, also at an even rate and at the slowest operational speed of the winch.

Each haul should last about 15 to 30 minutes from the time of launching the net until its recovery. The speed of the vessel should be adjusted so that the wire angle remains at about 60° (55° to 65°) during the course of the haul.

Horizontal hauls may be made with one or more nets attached to the towing cable at one time. The lowermost net (or the one net, if only one is used) is attached to the towing cable as described above. For these hauls the weight should be as heavy as can be handled, at least 50 lb, and preferably of streamlined design, as a minimum wire angle is desired. Additional nets are attached to the cable by means of wire clamps. It will be necessary to estimate from the amount of wire out and the stray angle the points at which the additional nets must be attached in order for them to operate at the desired depth levels.

The complete haul should last about half an hour in order to minimize the contamination from levels other than the towing level. The nets should be raised or lowered as rapidly as possible without fouling the gear or putting undue strain on the silk mesh. As the nets reach the surface at the completion of the tow, they are detached from the cable with as little loss of time as possible.

Vertical plankton tows are taken while the ship is on station. A proper weight is attached at the end of the net (4 to 8 kg). The net is lowered usually to 100 m depth and hauled at a speed of 0.5 to 1m per second. The closing nets are operated in the same manner, lowering them to the required depth, hauling the required distance, closing with a messenger while hauling the last few metres at the required depths and then the net is brought aboard by continuing to haul.

After the tow, the nets should be stretched out to dry in a protected location out of the sun, and secured in such a way that there is no chaffing of the silk. When the net is dry it should be carefully checked for snags and holes. Any moderate damage to the mesh can be repaired with a very fine needle and thread; very small holes can be repaired with adhesive tape, or with household cement if the break is in the 56XXX mesh.

At the end of the trip each net must be thoroughly washed in freshwater, shade dried, and necessary repairs made.

As each net is brought aboard at the conclusion of the tow, the bucket is detached from it and the contents washed into an enameled saucepan. The material is then transferred by means of a plastic funnel to a quart jar and sufficient neutralized formaldehyde added to produce approximately a 4% solution of formaldehyde. Add a small pinch of borax to each sample. As deterioration is rapid, the sample should be preserved as soon as possible after it is removed from the water.

The label for each plankton sample should include the following:-

(1) Abbreviated vessel name

(2) The cruise number

(3) The station number

(4) The sample number

(5) The ship's position (if known at the time label is prepared)

(6) The net number

(7) Depth (if a horizontal tow)

(8) Meter number

(9) Meter reading

(10) Date

(11) Observer

If the sample is split between two jars, one label should read "1 of 2" and the other "2 of 2".

For each station it is imperative that the *plankton log* be completely filled out (see Form 13).

The ship's position should be recorded from celestial or Loran fixes. When a fix is obtained, the station positions intervening from the previous fix must be interpolated and the correct position recorded on the log.

The bridge will keep a record of the course and of the tachometer readings (RPM) during the haul.

The time should be recorded when each net enters and leaves the water. The wire angle and amount of wire out (in metres) should be recorded at 2-minute intervals during the haul.

The current meter must be accurately read at the end of the haul.

The following symbols are used:-

B = Oblique

H = Horizontal

N = Plankton tow-net, followed by a number indicating the diameter of the ring frame in cm.; e.g. = N 100

V = Vertical

The measurements of quantities of collected plankton is often made in the field. Two methods of volume measurement are most commonly used. The measurement of *displacement volume* is more accurate than the measurement of *settling volume.*

To measure the displacement volume, the plankton sample is filtered through a piece of fine bolting silk (No. 25) and the piece of silk with the retained plankton is placed on an absorbent paper for 10 minutes. Then the sample is poured back into the preservative in a graduated cylinder (or conical graduated glass). The increase of the volume in the graduated cylinder is recorded as the displacement volume.

To measure the settling volume, the plankton with the preservative is poured into a graduated cylinder (or conical graduated glass). The sample is left to settle for 3-6 hours or more and the volume occupied by the plankton after this period, is recorded as the settling volume.

5.2 NEKTON

In addition to the work on economic species, described in Chapter 1, other fish in the study area may have to be observed and collected. Collection is usually done with commercial fishing gear. Details of the gear used, location, depth of water and the time of fishing must be recorded. Special collecting gear is sometimes used, such as young fish trawls and large vertical plankton nets, for sampling fish larvae and megaloplankton.

Special experimental gear, which usually is a miniature commercial fishing gear, is used from research vessels to catch pelagic animals.

Some nektonic animals, which spend part of their life on or close to the bottom are caught with beam and high-speed dredges.

Observations on the appearance of nekton should be made besides direct collecting, for example, fish shoals, flying fish, mammals, the behaviour of the shoal etc. seen, should be noted in the log.

All observations on pleuston such as of floating logs, floating seaweeds, the discolouration of the sea, etc., should also be carried into the log.

5.3 BENTHOS

The qualitative study of benthos is usually conducted with various dredges, such as the regular beam dredge, the scoop, the anchor, and the high speed dredge for catching fast-moving animals on the bottom, bottom plankton net, etc.

In dredging, care should be taken that enough cable is paid out (at least 3 times the depth of the water) and that the dredging speed is not too high, to ensure that the dredge is towed along the bottom. In shallower water the vibration of the cable will tell whether the dredge is on the bottom or not.

Considerable skill is needed when dredging on rough bottoms and the rigging of gear for rough bottom differs from that for good bottoms. It is often advisable to arrange a "weak spot" close to the dredge so that if it catches immovably on a rock, the gear is detached and perhaps lost, but no damage is done to the cable or winch.

Attempts have been made to mount counting wheels on the dredges for determination of the length of haul. These counting wheels function satisfactorily only if the dredging speed is slow, the dredge relatively heavy and the bottom consists of consolidated material. In most cases however dredges jump considerably on the bottom and/or dig occasionally into soft material and incapacitate the counter wheel and the estimate of the length of haul becomes questionable.

Submarine photography and television has been used on a few occasions for investigations of epifauna. Although these instruments give a picture of the nature of sediment surface and the population of macro-epifauna on it, they are not useful for quantitative benthos work for fisheries purposes, because the infauna on the surface layer is usually the most important benthos fish food.

Various grabs are used for quantitative studies of benthos (see Figure 11), the most common being Petersen and Van Veen grabs, which have a working area of 0.1 or 0.2 m^2. The spring loaded grab is among the more expensive and complicated devises for this work. The various grabs usually have different working capacities according to the kinds of bottom, and a volume correction can be applied for greater precision.

The bottom sample upon arrival on board is washed through a set of sieves (usually with 2, 1, 0.5 and 0.2 cm mesh openings) after a small (about 50 g wet weight) composite sample of the bottom substrate is taken for sediment study. The animals are carefully collected from the screens and preserved in 60% alcohol or in 4% formaldehyde. The containers are labelled with the following data: date, position (station number), depth of water, the area of grab, the volume of sample, name of the collector and special information such as the environmental data T.S. and the type of sediment.

For a preliminary benthos survey on a limited fishing ground, 20 - 70 bottom samples give an approximate picture of the quantitative and qualitative distribution of benthos. It would be very helpful, when experimental trawling in unknown waters, especially in tropical and subtropical areas, if a number of benthos samples were collected at the same time.

5.4 BIRDS

The recording of abundance and behaviour of oceanic birds is very important for exploratory fishing and the location of fishing grounds. The following observations should be recorded:-

(1) The location and time;

(2) Time of the observations;

(3) The species of bird;

(4) Their abundance;

(5) Direction of movement;

(8) Flocks or single and the kind and size of the flocks;

(7) Floating or flying;

(8) Other behaviour (e.g. feeding on fish, diving activities, etc.).

5.5. SOME REFERENCES ON PLANKTON AND BENTHOS OBSERVATIONS

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5.6. EXPLANATION OF TERMS IN SECTION 5

Benthos - Animals (and plants) living on or in the bottom substrata (in the water).

Biomass - The live weight of animals or plants.

Biota - The flora and fauna of a region.

Community - association - biocoenose - A definite group of species living in specific conditions in a biotope.

Dredge - An iron frame with a bag net attached, dragged over the sea bottom.

Forceps - A pair of pincers or tongs.

Habitat - The natural abode of a plant or animal especially the particular location where it normally grows or lives.

Nekton - Actively swimming pelagic organisms.

Petri dish - A small shallow dish of thin glass, with a loose cover.

Phytoplankton - (Plant plankton) - Microscopic plants growing in the water mass.

Plankton - The passively floating or weakly swimming animal and plant life in a body of water.

Pleuston - Organisms occurring in or on the surface layer.

Rubber policeman - A piece of rubber with a relatively sharp edge, used for cleaning surfaces.

Standing crop - The amount of animals or plants under a unit surface or in a unit volume of water at a given moment.

Zooplankton - (Animal plankton) - Minute animals with limited mobility. living freely in a water mass.

Form 13

Plankton Log

a. *Sheet No.* . .

b. *Vessel* .... . c. *Cruise No.* ....

		1	2	3	4
d.	Station No.				
e.	Position { Lat. ..... Long.				
f.	Date ..... Hour { start ..... finish				
g.	Gear No. ..... and description				
h.	Flow meter { start ..... finish ..... Difference				
i.	Wire angle (average) ..... Wire out				
j.	Course of tow ..... Speed of tow				
k.	Wind force ..... Sea				
l.	Jar No. ..... Preservative				
m.	Quantities measured				
n.	Remarks (e.g. clogging)				
o.	Observer				

NOTES ON FORM 13: PLANKTON LOG

1–4 – One sheet can be used for 4 tows.

e. – Give exact position in offshore water by latitude and longitude. In coastal areas a descriptive position can be entered.

f. – Give the starting and finishing time of actual tow.

g. – Give the number of the sampler and the type of the net (or other gear), the size (if necessary) and state the number of the net size (mesh opening of the net).

h. – If the sampler is provided with a flow meter, give the meter readings and computed number of revolutions.

i. – Give the wire angle and the amount of wire out for computation of the depth. If oblique hauls are made, state the changes of angle and amount of wire out during the tow.

j. – State the direction (course) of tow and the speed of vessel.

k. – Give wind force according to the Beaufort scale and the appropriate sea code number.

l. – Give the number of the jar where the catch is preserved and the kind and concentration of preservative.

m. – Give the quantities if measured or estimated on board by displacement or settlement volume and add a short description on the composition of catch by visual observations.

n. – Make remarks on degree of clogging, misbehaviour of gear, etc.

Form 14

Plankton Net and Flow Meter Calibration Sheet

a. *Meter No.* ..... b. *Date* .....

c. *Net dimensions and mesh size* .....

d. *Ship* ..... e. *Cruise* ..... f. *Location (Station)* .....

1 Trial No. and direction	2 Time start	3 Time finish	4 Tim difference	5 Speed of tow Knots or m/sec.	6 Length of tow	7 Counter reading Start (A)	8 Counter reading Finish (B)	9 Total Counts (A–B=C)	10 Litres Strained	11 Litres per Count	12 Comments

NOTES ON FORM 14: PLANKTON NET AND FLOW METER CALIBRATION SHEET

This sheet is used for relative calibration of flow meters with nets in the sea on an exactly determined distance, but at different speeds of the vessel. The relative amount of water filtered per count varies with speed. It should not be assumed that 100% of water is filtered even at lower speeds, but to obtain the absolute amount filtered the flowmeter with net should be calibrated at a constant speed in hydraulic tanks.

1 – Give the trial number and indicate the forward and return tow (to eliminate the influence of currents).

5 – Compute the speed of the tow from the time and distance. Always state engine speed in RPM.

10 – Compute the "litres strained" from the opening area of net and the distance of tow. This is a relative value and should be corrected if the net is properly calibrated in a hydraulic tank.

Table 20

Summary of plankton nets and their catching power, compared with the Hensen egg-net, taken as 1
(after Künne, 1933)

Name of the net	Diameter of the opening of the complete net cm	Upper part of non-filtering material			Side length of the net bag cm	Net material	Free opening of the net meshes mm	Catching power in relation to Hensen egg-net
		Side length cm	Diameter of the upper ring cm	Diameter of the lower ring cm				
Hensen egg-net	73	55	73	100	130	No. 3 bolting silk cloth	0.30	1
Hensen egg-net without upper part	100				130	Ditto No. 3	0.30	1.03
Nansen net	70				290	Ditto OXX and No. 8	No. OXX:0.57 No. 8:0.21	0.87
Standard net	50				225	Ditto No. 3	0.30	0.1
Standard net	50				235	Ditto No. 25	0.05	0.09
Large vertical net with upper part	200	60	200	233	430	Muslin, No. 22	0.93	8.3
Large vertical net with upper part	200	60	200	233	430	Tulle	2.40	6.1
Large vertical net without upper part	212				720	Stramin	1.00	4.0
Heligoland larva net	143	60	143	160	233	Bolting silk cloth No. 0	0.54	4.1
Medium Apstein net	13	23	13	40	90	Ditto No. 20	0.07	0.025 (0.036)

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